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306TH MEETING, OCTOBER 9, 1928

H. V. WILSON: *Some Guiding Ideas in Biology.*

In the work of science facts are not picked up as discrete, isolated bits of knowledge. We are led to their discovery through the formulation of questions.

One of the oldest questions is, how deep can our knowledge go? The naïve materialist affirms that it goes to the bottom, that research reveals the stuff, the very substance, of which the universe is made. That is, he interprets the units of interchanging matter and energy of our contemporary physico-chemical theories not only as phenomenal realities which we might see were our senses fine enough, but as ultimate realities, aside from which there is nothing.

The idealist looks on such thinking as picturesquely ingenuous and the conclusion as incredible. He calls to mind that all that we really know is that we have certain experiences. These conscious states, he tells us, are projected and make up our perceptible world which thus becomes, throughout, a world of mind. Idealism in its essence has fascinated many men of science. Huxley for instance, writing about 1880, says that if it were necessary for him to choose between materialism and idealism, he would adopt the latter view.

Perhaps in strict logic it is not necessary to believe in any external world at all. Yet, we all do except sometimes when engaged in argu-

ment. Our concepts of it, however, since they are products of the mind and stimuli arising from the assumed externality are most probably very different from the thing itself, which then remains unknown. We find ourselves in fact, as we analyze our knowledge and the physiological ways in which we get it, facing an impenetrable mist which conceals the real nature of the world of which we are a part. This is the "unknowable" of Spencer, the "ignorabimus" of Du Bois Reymond, assented to throughout his letters and essays by T. H. Huxley. Some may claim with Santayana, in one of his recent lectures, that there is nothing the presence of which we feel more intimately than this very unknowable. But while this may be true, it is also quite clear that we have no descriptive knowledge of it and apparently can attain none.

The effect of this conclusion on biological investigation is indirect but powerful. We are led, as we grow more reflective, to be more and more interested in observable fact, or as we may say in our experiences, and less interested in hypothetical explanations. Admitting, as we do, the great usefulness of the latter and indeed their necessity in our thinking, it is plain that the actual conquests of science are the generalized statements of observable fact. These are the ideas that serve as the tools with which we uncover more and more of the perceptible, get more and more experiences and so increase what we call our control of Nature's processes. We would go faster perhaps if we strove more successfully to combat a curious weakness, the tendency to state a set of perceptible facts in terms of the hypothesis that is formulated to explain them.

In illustration of the foregoing, three biological ideas may be adduced that have stood the wear and tear of time and may be looked on as solidly based generalizations. These are (1) The cell-theory, (2) The gradational arrangement of forms in series, seen everywhere in animal and plant groups, leading from lower or more generalized to more specialized types, (3) Embryonic recapitulation, in higher or more specialized forms, of types of structure that are permanent and characteristic in lower or more generalized forms. All of these generalizations are continually being verified by the discovery, to which their employment leads of more and more particular cases which conform to the rule.

If we employ, as we often do, in connection with such ideas as the preceding the term 'theory,' we use the word in a different sense from that in which we employ it in the case of ideas like the atomic-theory or the gene-theory of heredity. In these latter we assume or deduce the existence of bodies that are not directly perceptible. Whereas in

the case of the cell-theory and similar ideas we are merely continuing an expression which was appropriate when the generalization was an incipient one, that is based on few and homogeneous cases and in consequence of doubtful validity. In this sense we use the word 'theory' continually in ordinary life.

The relation to the evolution theory of the recapitulation process and the serial arrangement of forms is close. The evolution theory, as an account of genetic changes in animals and plants during the ages preceding our own, is an inference or deduction drawn from generalizations. The deduction is so obvious and the supporting generalizations so diverse and so rich in content that, in the absence of any other explanation, save transcendental ones, of the observable facts, our conclusion acquires such a high degree of probability that we are constrained to believe in its truth. And yet even here if we care for logic we recognize that observable fact and generalization take precedence in our classification of knowledge over deductions no matter how strong.

In contrast to well established generalizations, such as those that have been adduced, is the theory of self-adaptation. We apply this term to cases where in the developing germ or the injured adult a new type of behavior is called out by a set of conditions which make the usual, normal behavior impossible. The behavior is so "regulated" that the end result, although reached in new ways, is the same as in normal life. We now know many phenomena especially of regenerative nature which seem to be due to the working of this power of self-adaptation. W. Roux and H. Driesch regard it as among the primary powers of protoplasm. Perhaps as we continue to test out the idea, we shall find that we are dealing with a real process and have not been misled by superficial analogies into considering a mass of phenomena as homogeneous which later investigation will have analyzed into groups due to different and distinct causes. Biologists at any rate are better disposed toward it than formerly, since so many have learned, what was plain decades ago to others like W. K. Brooks, that science is at bottom descriptive and that the chemico-physical structure and processes of a protoplasmic mass (cell, tissue, organ, organism), no matter how important they are for us to ascertain, will not tell us what it will do or can do as a whole, and yet that is what, as biologists, we are chiefly concerned with, rather than with the subsidiary processes of oxidation, electrical change and the like, processes strictly within the field of the chemist and physicist, who yet are guided to their study by the discoveries of the biologist. How a protoplasmic mass correlates

the elementary physico-chemical processes so as to develop or otherwise function in a particular way, we have as yet no idea. The power is a part of the organization of the mass, we say. We discover it through observation, including under that head experiment, and in no other way.

For the present we may content ourselves with recognizing that self-adaptation is a lively and fruitful idea in the investigation of today. Quite possibly we have here a generalization in its most interesting phase, that is an incipient one.

F. K. CAMERON and H. D. CROCKFORD: *The Aqueous Solution of Cupric and Ferrous Sulphates.*

The solution isotherms at 30°C. have been plotted for the several systems involved, and the corresponding solid phases identified. Among the necessary consequences one must include:

1. The solubility of cupric sulphate in water is depressed by sulphuric acid.
2. The solubility of ferrous sulphate is depressed by sulphuric acid.
3. Cupric sulphate and ferrous sulphate mutually depress one another's solubility in water. The presence of sulphuric acid augments the depression.
4. A satisfactory explanation of the two solid phases in contact with an aqueous solution of cupric sulphate, ferrous sulphate and sulphuric acid is that one phase is cupric sulphate pentahydrate, $Cu\,SO_4\,5\,H_2O$, and the other a solid solution of ferrous sulphate, sulphuric acid and water.

307TH MEETING, NOVEMBER 13, 1928

T. F. HICKERSON: *An Exact Method for the Design of Continuous Beams and Columns.*

W. C. COKER: *The Flora of North Carolina.*

No recent list of North Carolina plants has been published. In 1822 Schweinitz published a synopsis of the fungi of North Carolina, the first important work on fungi to be issued in America. In 1869 Curtis brought out his *Catalog of the Indigenous and Naturalized Plants of the State.* In this he includes a total of 4849 plants, of which 1873 were flowering plants, the remainder, 2976, lower plants. In 1899 Hyams in *The Flora of North Carolina from Ranunculaceae to Salviniaceae* listed the flowering plants and ferns (with their allies), giving a total of 2685, of which 2622 are flowering plants. No general list has appeared

since. To the aforementioned list we have added, after subtracting some obvious errors, known additions to the flora and now have a list totaling about 5500, of which about 2800 are flowering plants. Within this list we include only the fungi listed by Curtis, but within the last fifteen years our Botanical Department here at the University has added many fungi to the state. We have not yet taken the time to add them up.

Compared with other states, the flora of North Carolina is extremely rich. From the evidence available, only Florida seems to lead this state in the total number of flowering plants and fern allies. Dr. Small, of the New York Botanical Garden, estimates the number of Florida as 3610 (3500 and 110, respectively). Mr. E. J. Alexander, one of our former students, now at the New York Botanical Garden, estimates the flowering plants of this state as 3100, and ferns (with allies) 68, or a total of 3168. If this estimate is correct, we lead all states except Florida, so far as published information is concerned.

On account of the importance and special interest in trees, we note that Florida has 328, North Carolina 199, Louisiana 196, Texas 198, Alabama 136, Georgia 134, Pennsylvania 189, Indiana 127, West Virginia 125, California 94. It should be mentioned, however, that comparison by exact numbers is impossible, as different authors treat the subject differently and as some include as trees plants that others list as shrubs. Judgment as to species and varieties also varies greatly.

308TH MEETING, DECEMBER 11, 1928

OTTO STUHLMAN: *The Physical Characteristics of Kunzite and Hiddenite.*

G. R. MACCARTHY: *Unstable Continents.*

309TH MEETING, JANUARY 15, 1929

H. D. CROCKFORD: *The System $CuSO_4-H_2SO_4-H_2O$.*

The system: cupric sulphate, sulphuric acid, and water has been investigated at 0°, 30°, and 40°C. The following conclusions have been established.

1. The solubility of cupric sulphate is depressed by the presence of sulphuric acid.
2. The solubility of cupric sulphate in sulphuric acid solutions increases with rise of temperature.
3. The solid phases found in this system are: cupric sulphate

pentahydrate, cupric sulphate trihydrate, cupric sulphate monohydrate and anhydrous cupric sulphate. The amount of water of crystallization decreases with increase in the concentration of sulphuric acid.

4. The data of Bell and Tabor[1], and Foote[2], for this system at 25°C. have been confirmed.

H. H. WILLIAMS: *The Third Problem in Logic; the Transition from Law to Truth.*

310TH MEETING, FEBRUARY 12, 1929

H. W. CRANE: *The Use of the Motion Picture in Clinical Studies.* (Illustrated.)

R. W. BOST: *Tin Tetraphenyl—A New Reagent in Organic Syntheses.*

Reactions between tin tetraphenyl and the following compounds were studied: Halogens, alkyl halides, acyl halides, sulfur, sulfuryl chloride and nitric acid. With halogens monoaryl halides were formed. Alkyl halides react to give low yields of aromatic hydro-carbons, while acyl halides react to give ketones. Sulfur under different conditions of time of heating, temperature, and concentration of sulfur yields diphenyl sulfide, diphenyl disulfide and thianthrene. Nitric acid reacts violently to give nitrobenzens. The reaction with sulfuryl chloride gives a variety of products.

311TH MEETING, MARCH 12, 1929

G. M. BRAUNE: *Tests on the Yadkin River Bridge.* (Illustrated.)

J. F. DASHIEL: *Effect of Emotional Excitement upon Rational Behavior.*

Hamilton's "quadruple choice" method of determining the different levels of perseveration reaction tendencies shown by different animal species and different ages of humans, was applied to the question implied in the title of this paper. His method consisted essentially in presenting a subject with a situation not completely soluble but calling forth persistent attempts, and in noting and grading the character of these attempts,—which were found to vary in adequacy from those (highest) of the adult humans, through those of young or defective humans, those

[1] Bell and Tabor. J. Phys. Chem. **12**: 175. 1908.
[2] Fote. J. Amer. Chem. Soc. **37**: 290. 1915.

of monkeys, and those of mature dogs, to those (lowest) of puppies and cats. In the present experiment college students were found to react ordinarily on the highest level; but when subjected to emotionally exciting stimuli (loud auto horn, cold shower, electric shocks) their behavior fell to the lowest level.

312TH MEETING, APRIL 16, 1929

ARCHIBALD HENDERSON: *Einstein.*

D. A. MCPHERSON: *Hideyo Noguchi—Martyr to Science.*

313TH MEETING, MAY 14, 1929

H. V. WILSON and J. T. PENNY: *The Regeneration of the Epidermis in Sponges Grown from Dissociated Cells.*

The epidermis of the adult sponge, *Microciona prolifera*, is a continuous sheet of protoplasm which is devoid of cell outlines and in which the nuclei are irregularly scattered. The mesenchyme is composed of eight different types of cells which are recognizable by their nuclei and inclusions. The bulk of the dissociated tissue and of the early reunition masses is made up of two of these types of mesenchyme cells and of collar cells.

The epidermis of the sponges grown from dissociated cells is formed from mesenchyme cells of a particular type. These cells form a layer at the surface of the early reunition mass. They flatten out, become continuous with one another, and eventually form a thin film in which the inclusions typical of the cells taking part in this formation are arranged in a single layer. These inclusions disappear and the film assumes the adult condition.

W. M. MEBANE: *The Solubility of the Phosphates of Calcium in Aqueous Solutions of Sulphur Dioxide.*

COLLIER COBB: *Cliff and Cave-dwellings and Petroglyphs Along the Tuckasegee, Little Tennessee and Nantehala Rivers in North Carolina.*

In the summers of 1881, 1882 and 1883, I visited these cliff-dwellings in company with Suate Owl, George W. Bushyhead, the deposed chief, and Nimrod Jarrett Smith, the then chief, of the Eastern Band of Cherokee Indians. These all three assured me that their forebears had used these caves as permanent habitations, and that they had been

inhabited by men who were before the Indians came. They also told me that the petroglyphs told the story of the settlement of the aborigines but that none of the Indians could read their writings.

I have photographed many of the cliffs and all of the inscriptions I have found, and I have tried to prevent any digging on the floors of the caves until some one properly trained for the work could undertake their investigation. My interest in the matter is that of the human geographer,—not the archaeologist.

COLLIER COBB: *A Small Fossil Elephant from the Everglades of Florida.* (Exhibit of the bones.)

The bones were exhibited but no outline of the paper was furnished.

A PARASITIC ALGA, CEPHALEUROS VIRESCENS KUNZE, ON CITRUS AND CERTAIN OTHER PLANTS

By FREDERICK A. WOLF

PLATES 24–28

INTRODUCTION

Botanists, generally, have such a meagre knowledge of parasitic algae, because of their paucity, infrequent occurrence, and limited distribution that any consideration of these plants is of unusual interest. This communication deals with one of these forms, *Cephaleuros virescens*, which first came under my notice in 1926 while stationed in Orlando, Florida, at the Laboratory of the United States Department of Agriculture for the study of insects and diseases of *Citrus*.[1] Although this alga has been studied from time to time by various workers in other parts of the world, no investigation of it, beyond mere mention of its occurrence, has been made within the United States. In fact, no comprehensive study has been made of it anywhere within the past two decades. The writer's attention was centered on this plant primarily because of the light which its investigation might reflect on the problem of "the degenerative influence of parasitism." Accordingly, an interrupted investigation, extending over a period of four years, has been made of its pathogenicity and of the relationship of alga and suscept. These observations have been assembled herein and, in addition, a summary has been made of the observations of others, many of which are conflicting.

SUSCEPTS

Cephaleuros virescens appears to be widely distributed on a wide range of plants in tropical and subtropical countries. It occurs primarily on leaves but has been collected in addition on the twigs and

[1] The writer severed his connection with this Laboratory September, 1927, and additional field observations were made in September, 1929. Much valuable help which is hereby gratefully acknowledged was received through the courtesy of Messrs. O. C. McBride, Associate Entomologist, W. W. Yothers, Entomologist, Bureau of Entomology, U. S. Department of Agriculture, and J. R. Springer, Florida State Plant Board, Orlando, Florida.

fruits of several species. Within the United States it occurs in Florida and undoubtedly in the other Gulf Coast States as well. A report was made by Stevens (26), in 1918, that specimens had been taken on *Citrus* in widely separated localities in Florida. Burger (2) in 1923 and the Plant Disease Survey bulletins (30, 31) in 1924 and 1927 also noted its presence there on *Citrus*.

The writer's collections have been made in the following places on the following suscept species: Grapefruit (*Citrus grandis*) at Ellington, Fla.; sweet lemon (*Citrus limonia*), Cuban Shaddock (*Citrus grandis*), tea (*Camellia Thea*), and magnolia (*Magnolia grandiflora*) at Orlando, Fla.; loquat (*Eriobotrya japonica*) at Apopka, Fla.; avocado (*Persea americana*), Spanish jasmine (*Jasminum grandiflorum*), tangerine (*Citrus nobilis* var. *deliciosa*), Temple orange and magnolia at Oakland, Fla.; and cinnamon (*Cinnamomum zeylanicum*), fringe tree (*Chionanthus virginica*), shiny privet (*Ligustrum lucidum*), crape jasmine (*Tabernaemontana coronaria*), bay (*Gordonia lasianthus*), Spanish jasmine, Cattley guava (*Psidium Cattleianum*), coral berry (*Ardisea crispa*), magnolia, haw (*Viburnum tinus*), and tea at Maitland, Fla.

Numerous reports have been made of the occurrence of this alga in the West Indies. Earle and Rodgers (9), in 1915, noted that the trunks and limbs of *Citrus* trees in the Isle of Pines were at times so abundantly covered by this plant as to result in a stunting of the trees. Limes and lemons appeared to be more seriously affected than either oranges or grapefruit. Cook and Horne (4), in 1908, observed it, in Cuba, on limes, bergamot oranges and other species of *Citrus*, but regarded it as of minor importance. Johnston and Bruner (16) in a bulletin on *Citrus* diseases in Cuba also mentioned its occurrence. Stevenson (27), in 1918, reported its presence in Porto Rico as has been subsequently done by Cook (31). Nowell (22) in the Lesser Antilles, investigated this alga in its relationship to a disease of cacao (*Theobroma cacao*), but noted it also on other species.

Several recent records of its presence in northern South America have been made. Toro (29) observed it to be abundantly present in dry seasons on the leaves of *Inga* species in Colombia and Weir (35) on rubber (*Hevea brasiliensis*) in the Amazon Valley. It appears doubtful in view of the wide suscept range of the alga under consideration whether *Cephaleuros pulvinatus* described by Schmidle (24) on avocado, in Equador, is distinct from *C. virescens*.

An examination of herbaria containing collections of tropical plants would beyond doubt reveal its presence on many other plants. Among

the specimens in the herbarium of the United States Department of Agriculture, Office of Pathological Collections,[2] which appear to be identical with this plant are the following:

On avocado, Dunedin, Fla., *Gardenia jasminoides*, St. Petersburg, Fla., *Psidium guayava*, Brooksville, Fla., *Bishoffia japonica*, Oneco, Fla., and *Mangifera* sp., Homestead, Fla.; on *Cinnamomum camphora*, *Viburnum tinus* and *Magnolia* in Louisiana; on avocado, tea, and privet in Cuba; on *Ocotea leucoxylon*, *Achras zapota*, *Chrysobalanus icaco*, hibiscus, lime and lemon in Porto Rico; on *Oryctanthus ruficaulis*, and *Phoradendron crassifolium* in the Amazon Valley; on an unnamed plant in Nicaraugua; and on *Dolichandrone* in Uganda.

A knowledge of this alga in the Old World dates with the investigations of Cunningham (6), in India, in 1877. He observed it first on mango (*Mangifera indica*) eight years earlier. His investigations were concerned primarily with a destructive blight which it caused in the Kamaon Hills on *Camellia japonica* but he noted it also on *Rhododendron*, crotons and ferns. Ward (32) in 1884 observed it in Ceylon on *Coffea liberica*, *Ixora*, *Thea*, *Mimecylon*, *Eugenia*, *Anona*, *Elaeagnus*, *Magnolia*, *Citrus*, *Durio*, *Sideroxylon*, *Quassia* and *Michelia fuscata*. Karsten (17) found it to be very prevalent in Java, lower India, Singapore, and Ceylon and stated that it occurred on practically every tree and shrub in the Botanical Gardens at Buitenzorg, principally on members of the family Apocynaceae. It was especially abundant on such hairy, leathery-leaved species as *Urostigma Rumphii*, *Gnetum* sps., *Bowenia spectabilis*, and *Strychnos nux-vomica* but sparingly present on such smooth-leaved species as *Chrysophyllum aureum* and species of the genera *Uvaria* and *Unona*. Other plants listed by him include *Canarium commune* and nutmeg (*Myristica fragrans*). The same alga was noted by Cunningham (7), in 1887, on *Limnanthemum indicum*.

Watt (33) in 1898, Cunningham (8) in 1897 and Mann (18) in 1904, each reported the occurrence of a serious disease of tea in India due to this alga. Mann and Hutchinson (19) made a thorough-going study of this tea disease and called it "red rust." They found that the lowermost leaves and those near the center of the tree, and thus least illuminated, were most subject to attack. Twigs, larger limbs and fruits were also diseased. They noted, in addition, that it attacked various trees and shrubs, among those not previously mentioned being *Cinnamomum iners*, *Albizzia stipulata* and *Tephrosia candida*. Butler (3),

[2] Thanks are extended to this Office for the use of these notes.

in 1918, stated that it was present on the larger part of the tea-growing areas of India and that a complete list of plants subject to attack there would exceed one hundred species. It is said also to be especially destructive to cacao in central Africa in the Belgian Congo (3).

APPEARANCE OF THE DISEASE

The alga itself is a characteristic sign of this disease. Its appearance is so distinctive that there is little likelihood of confusing it with anything else, even with other epiphyllous and epixylous algae or lichens which sometimes occur in situations where high temperatures and high humidities prevail. It occurs primarily on the foliage but may also attack twigs, and fruits, especially of tea and coffee, forming reddish-brown to orange colored patches whereas these other forms are grayish green to yellowish green. The appearance of lesions on *Citrus* (plate 25) is entirely similar to those on other suscept species (plates 24 and 26). The spots are cushion-like, circular to irregular in outline and when examined with low magnification the surface appears velvety and the margin dendritically lobed. This velvety coating is due to sterile hair-like outgrowths or trichomes which project perpendicular to the vegetative thallus. In the case of *Citrus* and other species destitute of epidermal hairs, the lesions occur on either leaf surface. On such plants as magnolia, avocado and loquat, whose lower leaf surfaces are hirsute or tomentose, the algal patches are confined to the upper leaf surface. The tissues beneath old lesions are moribund or dead and may appear from the opposite leaf surface as dry necrotic areas.

The lesions on twigs tend to be elongated and, because of their abundance, may fuse and girdle the twigs. When the lesions are abundantly present on the smaller limbs of *Citrus*, the trees are, in consequence, stunted. In the case of tea, as described by Mann and Hutchinson (19) the foliage distal to the girdle becomes yellowish and the trees present the appearance of "blight." Twigs which bear algal patches in quantity seldom recover.

In studying the relationship of alga to suscept both free hand and paraffin sections were cut parallel to the leaf surface as well as perpendicular to it. Examinations have been made of sections of lesions on the leaves of grapefruit, tea, loquat, avocado and magnolia. All show an endophytic thallus one cell-layer in thickness at the margin but several cell-layers in thickness at the center of old thalli. The thallus is subcuticular at first in all cases and tends to remain confined to this location except in *Citrus*, where it comes soon to occupy the disrupted epidermal

cells or the space between them and the palisade parenchyma (fig. 25). Mann and Hutchinson (19) show a subepidermal thallus in tea. The leaf cuticle shows especially well in free-hand sections stained with a tincture of alkanet as a continuous protective covering over the alga. The presence of the algal patch results in a brown discoloration of the subjacent epidermal cells. Those nearest the margin of the thallus are least affected while those near the center may have been killed. Following this the palisade cells also become modified as may be noted in figures 22, 23, 24, 27. Divisions of the palisade cells appear parallel to the leaf surface resulting in layers of serially arranged cork-like cells in magnolia and tea. These cells may die and the lesions may eventually extend entirely through the leaf especially in the area beneath the centers of old thalli.

A well developed phellogen and phellem is formed in *Citrus* (figs. 25 and 26). This corky layer increases to the extent of forming an outgrowth which causes the lesion to project cushion-like above the leaf surface. *Citrus* is known to respond in quite the same way to mechanical wounds or to invasion by such fungi as the scab organism (5) or the melanose organism (1). No such excrescences were noted in magnolia, tea and loquat leaves.

Karsten (17) maintains that the alga may penetrate the leaf tissues and extend to the opposite leaf surface where it can form a patch. The same phenomenon has been observed in *Limnanthemum indicum* by Cunningham (7) and in tea and *Cinnamomum iners* by Mann and Hutchinson (19). The writer has not noted such cases in any of his sections. The alga appears to force its way along between the cuticle and outer epidermal wall, splitting these members apart, by expansion during growth. This is shown at the margin of the expanding thallus by the lack of dissolution of the cuticle or of the outer wall of the epidermal cells. At this point and in all places they are of the same thickness as in normal tissues and have the same staining reactions. Moreover the alga crowds between the epidermis and palisade cells in the same manner and there is no evidence of a dissolution of the cell walls nor of the middle lamella at any point. Further evidence against the production of enzymes by this alga appears from its inability to enter the leaf by direct penetration, as will be pointed out subsequently.

Whether the death of cells beneath the superincumbent patch is due to the loss of their organic contents to the alga, to toxic products excreted by the alga, to the direct effect of shading, or to the withdrawal of water by the alga cannot be determined. At present there is no evidence

that the first two causes are effective. Undoubtedly shading exerts a baneful influence. Much of the deleterious effect could be expected to result from the loss of water and dissolved minerals which the alga secures by osmosis as the result of intimate contact and not as the result of any special structural device or physiological modification on the part of the alga. So far as its nutrition is concerned the alga is, in all probability, dependent on the suscept for water and dissolved minerals only. This conclusion finds support in the fact that it lives for a considerable period on fallen leaves which have been occasionally moistened.

THE ALGA

Resumé of taxonomy and relationship

The genus *Cephaleuros* was established by Kunze,[3] in 1827, from specimens collected on an unnamed coriaceous plant in Surinam by Weigelt. He described two species, one of which was *C. virescens*. His type specimens have unfortunately been lost but his characterization of the genus is as follows: "Thallus orbicular, lobed, formed of filaments of radiating cells like those of *Coleochaete* or *Melobesia*, the lower surface furnished with rhizoids containing colored protoplasm and the edges armed with sharp hairs, and from the discs arise thick, septated filaments terminated by a bunch of sporangia."

Fries (13), in 1829, modified Kunze's description and compared his plants with *Strigula*, a lichen.

In 1877, Cunningham (6) described as a new genus and species of algae, *Mycoidea parasitica*, which was often associated with a lichen or else was completely autonomous.

In 1884, Ward (32) worked out in detail the morphology and development of a lichen, *Strigula complanata*, occurring on banana shrub (*Michelia fuscata*) and other plants. He had access to Cunningham's preparations in rather unfavorable condition of preservation and concluded that the algal constituent of *Strigula complanata* was either identical with or a closely related species to the one which Cunningham had described from India. He classified the alga near *Chroolepus* but considered it as a member of a distinct line of development. However, both Cunningham and Ward figured and described a totally different fungus, the one discomycetous the other pyrenomycetous and of course a totally different lichen. In explanation it might be pointed out that Jennings (15) noted that in New Zealand *Strigula complanata* is asso-

[3] Kunze, O. Weigelt, Surinam Exsiccati.

ciated with *Phycopeltis expansa*, an alga closely related to *Cephaleuros virescens*. Furthermore, as is well known, the same species of alga may serve in a lichen structure as one member of the dual relationship for several different fungi.

Phyllactidium tropicum, described by Mobius (21) from Porto Rico, is probably identical with this same alga, as has been indicated by Thomas (28).

Hariot (14), in 1889, first pointed out that Kunze's genus *Cephaleuros*, founded 62 years earlier, is identical with Cunningham's *Mycoidea*.

A second step in the clarification of this synonomy was taken by Karsten (17), in 1891, while investigating epiphyllous algae in Java. He accepted the older name *Cephaleuros* instead of *Mycoidea*, but objected to the acceptance of *Cephaleuros virescens* Kunze as identical with *Mycoidea parasitica* Cunningham, since Kunze's specimens had been lost and his description was not sufficiently detailed to establish with certainty that Kunze and Cunningham were dealing with the same alga. He therefore called the organism *Cephaleuros mycoidea*.

In the light of our present knowledge of this alga and of its wide geographical and suscept range, these reasons, as pointed out by Mann and Hutchinson (19), do not appear to be sufficient to justify the abandonment of Kunze's name, *C. virescens*, and it is therefore herein retained. Cunningham (8), in 1897, came to this same conclusion. Moreover Karsten's employment of the specific name *parasiticus* in connection with a new species of *Cephaleuros* on *Calathea metalica* and on *Pandanus* species is not in keeping with accepted practices in modern taxonomy.

The systematic position of *Cephaleuros* and its interrelationship with other algal genera has been considered by various algologists. Karsten (17) placed it in the family Chroolepidaceae along with *Chroolepus*, *Phycopeltis* and *Trentepohlia*. This family includes all algae "living in air, characterized by the possession of haematochrom and formed by rapidly growing more or less ramifying cellular threads, with or without a covering of hairs." Oltmanns (23) is quite in accord with Karsten, as is the present writer, but includes the species of *Chroolepus* in the genus *Trentepohlia*. The family includes according to him all thread-like or shield-shaped algae, whose cells contain haematochrom and whose fructifications consist of spherical gametangia and of zoosporangia borne on crooked stalks and shed *in toto*.

Wille's (36) arrangement includes the family Mycoideaceae intermediate between the Chaetophoraceae and Coleochaetaceae. This

family includes five genera: *Chaetopeltis*, which occurs on fresh water algae; *Pringsheimia*, on marine algae; *Phycopeltis* and *Mycoidea*, on the foliage of land plants; and *Dermatophyton* on the carapace of fresh water turtles. He places *Trentepohlia* in the Chroolepideae, a tribe of the Chaetophoraceae.

Schmidle (25) would eliminate the Mycoideaceae of Wille and unite these forms with the Chaetophoraceae except *Dermatophyton* which he places in the Cladophoraceae. Previous studies of the biology of *Cephaleuros*, together with the present one, do not appear to show that its physiological peculiarities constitute a sufficient basis for separating it from morphologically related species.

Morphology and development

Thallus. The thalli of *Cephaleuros virescens* appear as circular, green to orange colored, velvety patches usually about a centimeter in diameter. Upon microscopic examination each thallus will be found to be a subcuticular or subepidermal disc one to several cell layers in thickness and with a dichotomously lobed, radiating margin (fig. 4). Orange colored hairs or trichomes extend to the surface through the cuticle or between the epidermal cells. Young thalli lack hairs although there may be a dense covering over the surface of older thalli. These hairs are of two kinds, sterile hairs, which are universally present on mature plants, and fertile hairs which develop during rainy periods. Each kind arises from a single thallus-cell. Sterile hairs are simple, rigid structures consisting of several cells and terminated by a taper-pointed cell (fig. 20); in contrast the fertile hairs are branched, giving rise to a fascicle of sporangia (fig. 11).

Stalked sporangia. In the development of fertile hairs an apical cell, which is to be the central cell, is delimited by a septum (fig. 6). This cell enlarges and gives rise to 4 to 8 thick, lateral and terminal protrusions (fig. 7). Each of these in turn becomes elongated and is terminated by a spherical capitellum (fig. 8). The elongated portion gradually develops into the pedicel or stalk cell and the terminal part into the oval or elliptical sporangium. A septum is meanwhile laid down between each sporangium and its supporting pedicel (fig. 11). At this stage, if moisture conditions are favorable the pedicels radiate stiffly from the central cell and the long axis of the sporangia, which are obliquely attached at the ends of the pedicels, tends to be perpendicular to the plane of the thallus. If, on the contrary, it is dry each pedicel

flexes or folds on itself and the sporangia are in consequence drawn close to the central cell (fig. 9). This peculiar arrangement of sporangia on crooked "neck" cells constitutes the "hakensporangien" of Karsten (17). Mature sporangia measure 38–40μ by 25–30μ.

The sporangia are liberated by a circumcissile splitting of the cellulose membrane at the juncture of pedicel and sporangium. Ward's (32) figures 28, 32 and 33 show that a circular opening is left for a time in this septum, affording a protoplasmic connection between the sporangium and pedicel as the iris-like septum is being formed and that at maturity a thin membrane covers this opening. The outer membrane of this septum tears first and finally the inner and thus the sporangium is freed *in toto*. Once the sporangia have been freed, the mechanism of abscission is apparent. Rings both on the pedicel and on the sporangia mark the outer and inner lamella (fig. 9). The rings and pore are best seen in empty sporangia (fig. 13). The sporangium wall is thinnest within the inner ring which marks the site of the ostiolum or pore through which the zoospores subsequently escape.

Swarming. Zoospore emergence has been repeatedly watched and accords essentially with Cunningham's (6) observations. When sporangia are dislodged and placed in a drop of water on a microscopic slide the entire sporangial content, which appears to be a uniformly orange colored mass, will within a minute begin to move. This movement is slow at first but within a few seconds will have increased to a violent agitation. At this stage the zoospores are fully formed but cannot be distinguished as individuals because of their rapid seething movement. By this time the ostiolum opens and the zoospores crowd out in a quivering stream. They separate from each other just outside the orifice by a jerking movement, pause for a moment, and then dart rapidly away. Less than a half minute is required for the zoospores, approximately 30 in number, to escape. Each is ovoid to elongate elliptical, 5–8μ in length, with two long flagella on the anterior end (fig. 12). After swimming around for about 10 minutes the movements gradually become slower, the flagella are then retracted and each zoospore rounds up and comes to rest (fig. 17). Occasionally one or two zoospores fail to escape and are therefore compelled to swarm within the sporangium.

If a mass of fertile hairs is mounted in water, and, after swarming has ceased, a fresh supply of water is added other sporangia may be induced to emit their zoospores. This procedure may be repeated several times.

Cunningham (6) noted that nearly all zoospores become distended and burst within a few moments after coming to rest. This phenomenon was of common occurrence in the writer's preparations of material mounted in tap water, rain water or distilled water. When a weak solution of sugar was substituted, however, to increase the osmotic concentration bursting was inhibited. It would appear from this that contact with soluble protoplasmic products from wounds or the saccharine excretions from scale insects and aphids is necessary for the continued existence of the alga.

Sessile sporangia. In addition to stalked sporangia, a sessile type of fructification is formed within the thallus. Cunningham regarded these as game tangia, an observation which Ward (32) and subsequent workers have not been able to confirm. Karsten (17) regards the sessile sporangia as of two kinds, those formed within but near the margin of the disc (fig. 15) and those formed at the ends of radial threads (fig. 5). Sessile sporangia and stalked sporangia may be present at the same time and may resemble each other in size and shape and in the fact that each originates from a single thallus cell. Sessile sporangia open in the presence of moisture by a fissure and emit swarm spores which appear identical with those from stalked sporangia. Observations in Florida show that in the period from the middle of May to the middle of September stalked sporangia are the more abundantly present and that during late fall, winter and early spring sessile sporangia are the more abundant.

Thallus formation. The course of development of zoospores into thalli has been traced by repeated examination of the same microscopic mounts over a period of several weeks and by scraping off young thalli from magnolia leaves and examining them. Here the larger proportion are wholly extra-cuticular and can be easily detached during a period of about a month beginning in mid-September. The zoospore on coming to rest, first increases in volume, becomes flattened and the wall becomes firm. Soon ingrowths which are to become septa arise from the periphery of this flattened cell and extend toward the center (fig. 18). Meanwhile the margin becomes slightly lobed and, as the ingrowths continue to elongate, secondary ones appear. Before the primary ones have converged at the center to make complete septa, tertiary ones may have started. By this time, also, projections at right angles to the primary ingrowths and arising from them, may have commenced to form and gradually become the transverse walls. Detached ends of walls are always evident in developing discs, a feature carefully described

by Thomas (28). As the thalli enlarge by marginal growth, the formation of additional radial and transverse walls continues in this same manner and eventually a circular, dichotomously-lobed, multicellular disc is formed (fig. 19). Each disc soon becomes irregularly lobed due to the fusion of thalli or to the unequal growth of lobes, and by the time they are a month old they have attained a size sufficient to be quite evident to the unaided eye.

Those discs which are superficial are dislodged within the first month. Those which have entered the leaf continue to enlarge for several years or as long as the leaves remain on the tree. They may even grow for a time on fallen leaves.

Isolation of the alga

Mann and Hutchinson (19) isolated and grew *Cephaleuros virescens* from tea in pure culture on gelatin enriched by tea leaf decoction, 1 per cent citric acid, and a small quantity of peptone. Isolations were made by placing sporangia on this medium. Under these circumstances "the alga was grown very successfully, the formation of the disc taking a perfectly normal course, but in the moist atmosphere of the culture medium and culture tube, no reproductive apparatus whatever was produced." The writer's isolations were made by planting fragments of thalli from *Citrus* and *Magnolia* on a synthetic medium of the following composition:

NH_2PO_4	0.5 gram
K_2HPO_4	0.2 gram
$MgSO_4$	0.2 gram
$CaCl_2$	0.1 gram
Iron	trace
Dextrose	5.0 grams
Agar	15.0 grams
Water	1000 cc.

Growth on this substratum was very satisfactory as witnessed by the fact that colonies 10 mm. in diameter developed within six weeks. The colonies were not cephaleuroid, however, but consisted of a cushion-like mass of loosely interwoven filaments (figs. 10 and 14) bright green to orange in color. Haematochrom was most evident in the exposed tips. No sporangia were developed in the three years in which this alga was maintained in pure culture. Among the additional substrata on which subplants were made were sterilized grapefruit leaves, grape-

fruit twigs, magnolia leaves, and synthetic agar containing grapefruit leaves. In some of the cultures which had been maintained six months or more without transfer, all of the pigments gradually disappeared. Under these circumstances the alga was fungoid in appearance and could readily have been mistaken for a fungus. No growth occurred, however, when subplants from such colonies were made on a fresh substrate.

Pathogenicity

Several investigations in the Old World have shown that *Cephaleuros virescens* may occur as the algal component of the lichen, *Strigula complanata*. A similar condition obtains in the New World as evidenced by several specimens among the pathological collections of the United States Department of Agriculture. One occurs on *Gardenia jasminoides* collected in Florida, in 1913, another on avocado in Cuba, in 1921, and another on mistletoe in Brazil, in 1923. However there is no evidence in the writer's collections that *Cephaleuros virescens*, in Florida, occurs in association with fungi to form lichens but instead is strictly autonomous. Miss Thomas (28) has recorded similar observations from material collected in Ceylon and Barbadoes. Cunningham (6), too, noted that it could live independently and concluded that it was pathogenic because of the destructive effects on the cells beneath the thalli. Also, Ward (32) observed that in some cases the alga passed its whole cycle of development without becoming invested by the fungal constituent of the lichen.

Grapefruit seedlings grown in the greenhouse were used for inoculation in the present study. The inocula consisted of sporangia or bits of thalli from magnolia or tea or else masses of filaments from pure culture. In some cases the inoculated plants remained covered with bell glasses for several weeks, others uncovered, some were placed in diffuse light, others in direct sunlight. Both wounded and uninjured leaves were inoculated and moisture was provided by atomizing, occasionally with distilled water or dilute sugar solutions. No infections developed in any case.

It does not appear that infections have ever been secured following artificial inoculations under controlled conditions. Further no one has traced penetration from the artificial sowing of zoospores. Ward (32) placed sporangia on leaves of *Coffea* and *Anona* on which thalli subsequently developed, presumably from artificial sowings. His studies,

it may be recounted, dealt primarily with the alga on *Michelia* on which he maintained that the thalli are entirely extra-cuticular. Mann and Hutchinson (19) were successful in infecting tea leaves and stems with zoospores from leaves but curiously enough no infection resulted when zoospores from stems were used as inoculum.

Sections of affected tissues reveal the most convincing evidence of pathogenicity of *Cephaleuros virescens*. As has been shown, the vegetative portions are characteristically endophytic, either subcuticular or subepidermal. The writer has noted on magnolia young thalli not over two or three weeks old which were entirely superficial. These, beyond doubt, could never effect lesions, but are either washed away or become desiccated and are blown away. Thalli on magnolia of sufficient size to be evident to the unaided eye are always subcuticular. It is believed that a similar condition obtains with all other suscept species, that nearly all young thalli succumb and that those few only, which chance to lodge in a crevice or abrasion succeed in becoming established within the suscept. When judged by the fact that lesions occur on leaf surfaces which lack stomata, and by the food habits of the alga itself, there seems little likelihood that the alga is able by direct penetration to enter the uninjured cuticle. Karsten (17) states that the cuticle of the alga fuses with that of the suscept. "Auch ich muss dafür halten, dase diese Cuticula von der Alge gebildet wird, doch geht sie ganz unmerklich in die Blattcuticula über. Diest stetzt eine innige Verschmelzung der Alge mit die Oberfläche des Wirtblattes voraus." The writer considers this conclusion to be based on erroneous observations. Fitting (12) says that *Cephaleuros* is at first epiphytic and becomes parasitic at maturity.

The parasitism of this alga must be regarded as of a very generalized type. This statement is based upon the fact, first of all, as has been pointed out, that it attacks essentially all kinds of plants with coriaceous leaves, a type commonly present in tropical countries, and is not restricted in its suscept range as are many highly specialized pathogenic fungi like the powdery mildews and rusts. It follows from this, secondly, that the alga does not withdraw from invaded tissue specialized, organic, chemical constituents, as do specialized pathogens, but is dependent on the suscept for water and inorganic salts only. These it can get from any broad-leaved evergreen. It is therefore considered to be a "water parasite," whose food material relationships approximate those of mistletoe, *Phoradendron* sps.

Moreover, there is no evidence of any degenerative influence of

parasitism or that *Cephaleuros virescens* is on the way toward ever becoming a fungus. It has no morphological nor physiological modifications by which it maintains itself except an apparent profligacy in the production of sporangia and zoospores. It has established its habitat in coriaceous leaves which furnish it a stable supply of water the year around and is furthermore constantly entirely shielded, except for the sterile hairs and stalked sporangia, against desiccation by the suscept cuticle above it. This alga is so situated manifestly, as to largely escape competition in the struggle for existence and is therefore to be regarded as a very unusual and remarkable plant.

Life history

Observations, in Florida, on the life cycle of *Cephaleuros virescens* have been directed mainly to its occurrence on *Magnolia*. Leaves which unfold in May remain free from infection throughout the entire summer. During the late September and early October, a few weeks after the close of the rainy season, infections become evident on these 4 to 5 months old leaves. Two months later prominent thalli, beset with sterile hairs, have developed. These thalli continue to enlarge throughout the winter and by the end of May, just prior to the beginning of the rainy season, and approximately eight months after infection, both stalked and sessile sporangia have developed. The length of this period of development from zoospores to thalli, bearing sporangia, corresponds with Mann and Hutchinson's (19) observations on tea. Successive collections of infected leaves, which unfolded during May of the previous year, were made on June 22, June 29, July 11, Aug. 2, Aug. 17, and Sept. 2, at all of which dates stalked sporangia were abundantly present, and swarm spores were observed. By November 11, stalked sporangia had become scarce but sessile sporangia were quite abundant. Swarming, even at this late date, readily followed immersion of the thallus in water. These thalli continue to grow throughout the second winter and bear successive crops of sporangia during the following summer and for as long thereafter as the leaves remain on the tree. The cells at the center of old thalli may finally become destitute of chlorophyll.

The fact that zoospores are produced in abundance during the entire rainy period and that no new infections have been seen during this time leads to the conclusion that they and any thalli which may have started to develop are washed away by the frequent rains. It was anticipated

that infections should take place on young leaves at the beginning of the rainy period rather than on mature magnolia leaves at the close of the rainy season. The same phenomenon occurs on grapefruit since the spring flush of growth was free from infection during the succeeding July and August while leaves from the preceding year bore lesions which must have been initiated about ten months earlier. Butler (3) has remarked that the stems of tea of the second year of growth are the ones which bear the alga in the fructifying condition, which accords with the observations which have been described on *Magnolia* and *Citrus*.

Control

The only extensive attempts which have been made to control this algal disease are those of Mann and Hutchinson (19) which were made in connection with its occurrence on tea. There appears to be a direct relation between the spread of the disease and the vigor of tea stems. If the plants are growing rapidly the patches are removed by exfoliation before the alga has penetrated the roughened bark sufficiently to produce injury. Proper cultural practices and pruning, of course, promote vigorous growth and are therefore recommended as one means of control.

As an additional means of control several investigators have suggested the application of fungicides. This is indicated by the fact that many algae are known to be very sensitive to fungicides, especially those containing copper salts, and by our knowledge of the cycle of development of this alga. The application of Bordeaux mixture to tea in winter was found to be beneficial (19). This beneficial effect of Bordeaux mixture on *Citrus* also is indicated by the observation that infected grapefruit trees in Florida occur in groves which have not been sprayed at least for a period of years for the control of scab and melanose. Further that groves in which the alga was once established, but which have been sprayed recently for the control of these diseases, are now free from this algal disease, whereas adjoining unsprayed groves are affected.

SUMMARY

This investigation is concerned with a parasitic alga, *Cephaleuros virescens*, which occurs in Florida on *Citrus* and various other trees and shrubs with coriaceous leaves. Various investigators have observed it widely and collected it in tropical and subtropical countries of both

the Old and New World on many kinds of plants. This study is mainly confirmatory of previous investigations in India, Ceylon and Java.

Leaves are the primary point of attack although lesions also occur on twigs and fruits. The disease can be recognized by the presence of velvety, reddish brown to orange colored cushion-like patches. This color is imparted by the pigment haematochrom.

The thallus is endophytic, either subcuticular or subepidermal. During the course of development both stalked and sessile sporangia are formed, from which biciliate zoospores are emitted. The cycle of development from zoospores to thalli which bear sporangia, has been observed on *Magnolia* and requires about eight months. Apparently a period of equal duration occurs on *Citrus*.

Infection of *Magnolia* and apparently of *Citrus* also occurs at the close of the rainy season on mature leaves. The alga is not commonly associated with a fungus to form a lichen in Florida. It is dependent on its suscept for water and mineral salts only, and therefore is considered a water parasite.

The alga remains alive and forms successive crops of sporangia until after the leaves are shed. Frequent rains wash off the young thalli, which are superficial, and apparently only those zoospores which effect penetration through wounds produce lesions.

The tissues subjacent to the alga die in the case of avocado, magnolia, loquat and tea without much cellular modification but are stimulated in *Citrus* to form wound cork.

The alga, on synthetic agar, forms a densely interwoven filamentous mass.

Cephaleuros virescens typifies a very generalized type of parasitism. It appears incapable of dissolving the cell walls of its suscept. As a result of its position, it is constantly supplied with materials for the manufacture of its own food, and is at the same time shielded against desiccation.

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EXPLANATION OF PLATES 27 AND 28

Figures 5–11, 13, 15–20 are drawn to scale shown near figure 10; figures 21–27 to scale near figure 21

Fig. 4. Surface view of portion of thallus showing habit of growth, pointed sterile hairs, stalked sporangia and sessile sporangia.
Fig. 5. Sessile sporangia borne terminally at the margin of the thallus.
Fig. 6. Tip of the developing fertile hair which has just delimited the central cell.
Fig. 7. Formation of protrusions or outgrowths from the central cell of a developing fertile hair.
Fig. 8. Early stage in the development of capitella-like processes which are to become sporangia.
Fig. 9. Tip of mature fertile trichome with characteristic crooked pedicels from two of which the sporangia have been shed. The sporangia are attached laterally.
Fig. 10. Chloroplasts and globules of haematochrom in filament from pure culture.
Fig. 11. Sporangia and pedicels have been formed and tend to radiate stiffly from the central cell.
Fig. 12. Zoospore with five chloroplasts and four granules of haematochrom.
Fig. 13. Empty sporangia, with concentric rings and ostiolum.
Fig. 14. Filament of the alga showing habit of growth, taken from pure culture.
Fig. 15. Sessile sporangium borne within the thallus.

PLATE 24

MAGNOLIA LEAVES AFFECTED BY CEPHALEUROS VIRESCENS

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PLATE 25

CEPHALEUROS VIRESCENS ON GRAPEFRUIT

PLATE 26

CEPHALEUROS VIRESCENS ON AVOCADO.

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PLATE 27

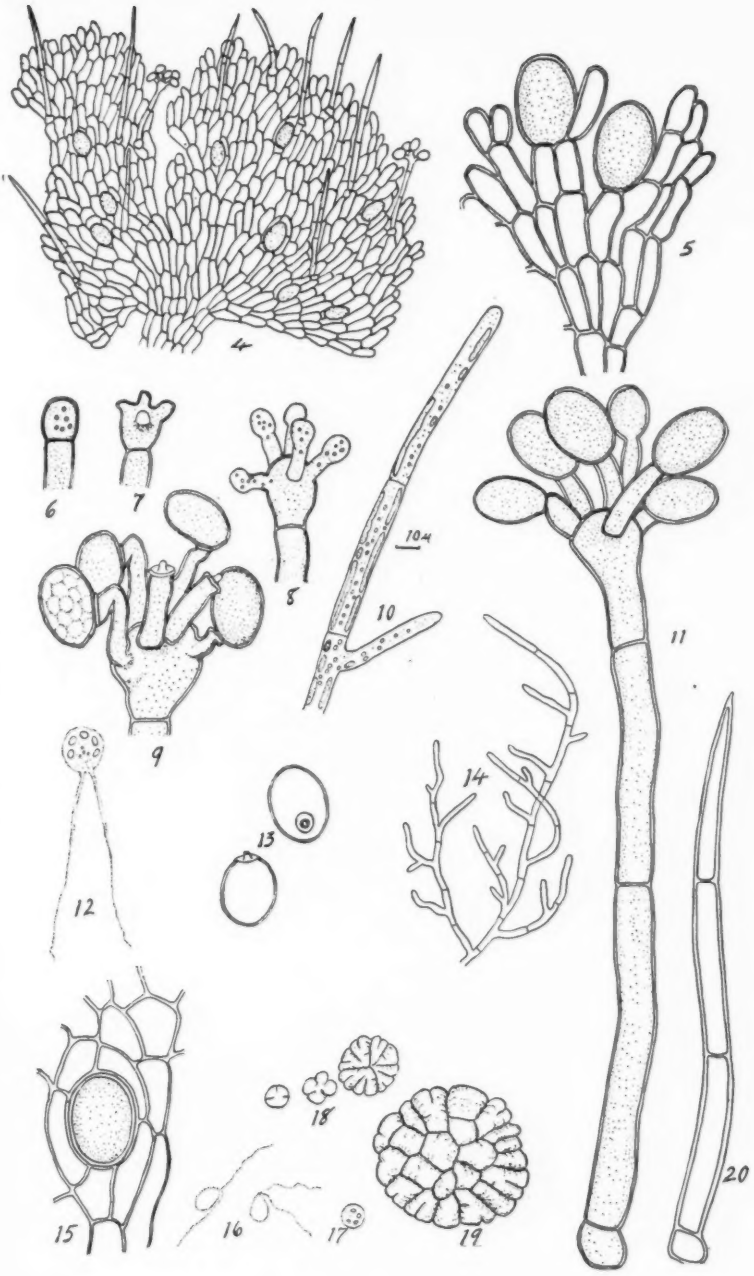

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PLATE 28

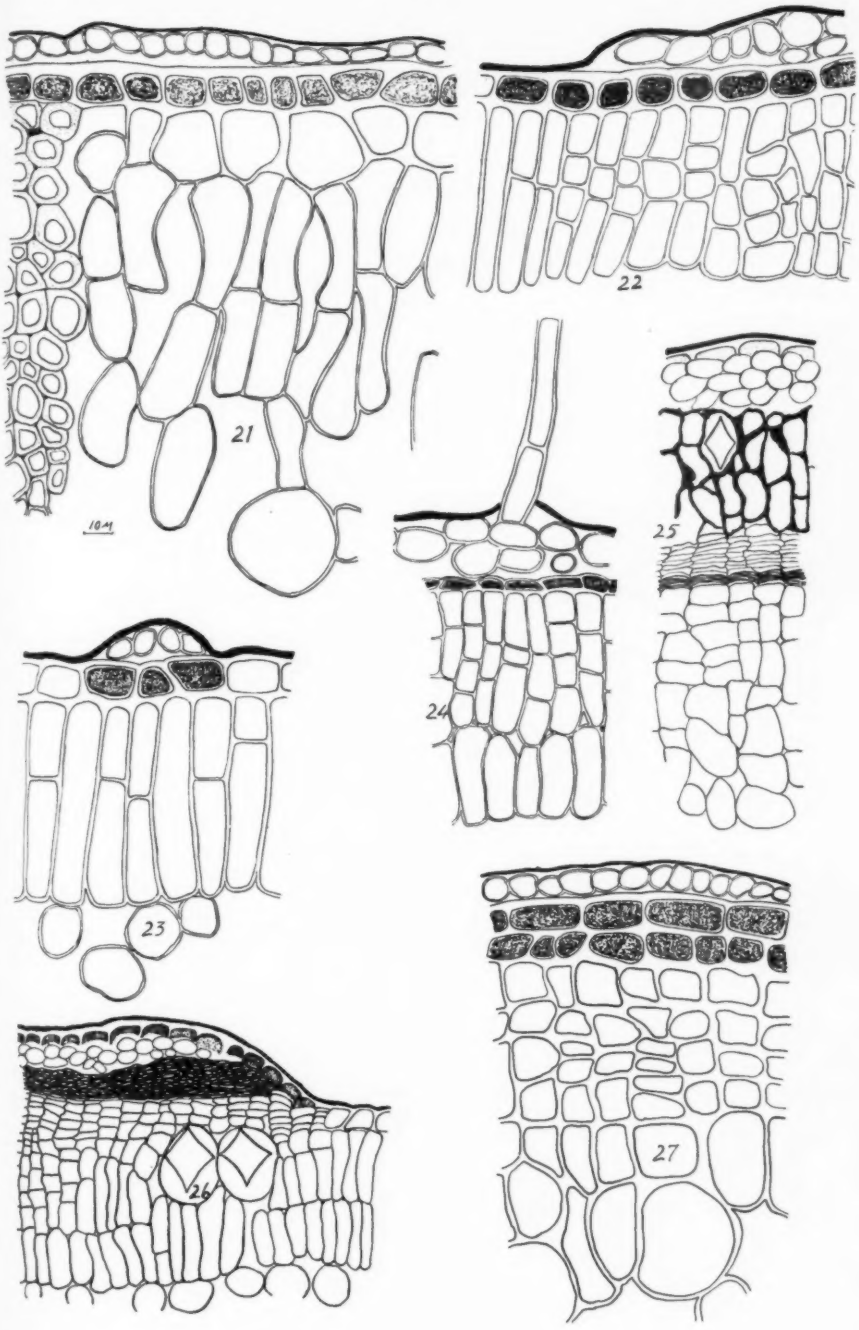

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Fig. 16. Motile zoospores.
Fig. 17. Cell which has retracted cilia and come to rest.
Fig. 18. Young stages in the formation of a thallus with radial and transverse walls in process of formation.
Fig. 19. Colony about three weeks old with dichotomously lobed marginal cells.
Fig. 20. Sterile trichome.
Fig. 21. Magnolia leaf in transverse section. The thallus is subcuticular. The epidermal cells are dead and their contents brown. Divisions of the palisade parenchyma parallel to the leaf surface have been initiated.
Fig. 22. Cross section of a leaf of avocado at the margin of a thallus which is subcuticular. The epidermal cells have been killed. The subjacent palisade cells have been stimulated to divide parallel to the leaf surface.
Fig. 23. Cross section of a tea leaf showing the tip of a radiating thallus-strand beneath the cuticle. Slight changes are evident in the epidermis and palisade parenchyma.
Fig. 24. Old lesion on avocado. Trichome projects through cuticle. Epidermal cells are discolored and palisade parenchyma is destitute of chlorophyll.
Fig. 25. Old lesion on grapefruit leaf. The thick walled cells beneath the thallus are modified palisade parenchyma. Beneath is a layer of phellem. Both the palisade and spongy parenchyma are concerned in cork formation.
Fig. 26. Transverse section of grapefruit leaf with the thallus beneath the epidermal cells. Just beneath the thallus is a layer of phellem whose walls are suberized. Beneath the phellem, is a phellogen, which has arisen by modification of the palisade parenchyma.
Fig. 27. Old lesion on tea leaf. The palisade parenchyma is strongly modified by the formation of septa. The uppermost layer is dead as is the epidermis above it.

OBSERVATIONS ON MATING HABITS OF CYCLOPS[1]

By L. L. Hill and R. E. Coker

Introduction

Since the time of Jurine's excellent work, the mating habits of several species of Cyclops have been observed by Claus (1857), Schmeil, (1892), Wolf (1905), Holmes (1909) and several others, although in most cases the observations of the mating phenomena seem to have been of a rather casual nature. As early as 1820, Jurine by careful observation and experiment established: (1) that mating occurred in Cyclops, (2) that without mating female Cyclops were sterile, (3) that one mating sufficed for the life time of a female,[2] and (4) that the modified antennae of the male were mere clasping organs and not the seat of the genital organs as Müller had supposed. His observations of the mating process were, however, very limited and he was lead to suppose that mating may occur by momentary contacts without clasping. He failed to observe the spermatophores, which were unknown as such at that time, and therefore his account was necessarily incomplete. Schmeil noted (1892) two modes of embrace in mating: almost universally the fourth swimming feet were clasped; only in *fimbriatus* (and probably also in *affinis*), was the embrace on the base of the abdomen held from above. Wolf, giving particular attention to mating habits, distinguished within the genus two groups of species: the one comprised species of typically cylopid form, such as *fuscus, vernalis, serrulatus* and *viridis*: for these the characteristic grip of the males were described and figured as being on the fourth pair of swimming feet of the female; the other group comprised *fimbriatus, phaleratus* and *affinis*—species generally regarded as

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The observations reported in this paper were made altogether by Hill; the second author has contributed by direction and by taking a considerable part in the examination of literature and the preparation of report.—*The authors.*

[2] This is now open to question; see p. 219, below.

transitional between Cyclopidae and Harpacticidae. For these the characteristic grip was about the abdomen near its junction with the cephalothorax. Holmes observed for *fimbriatus* the same mode of clasping as that described by Schmeil and Wolf. The two modes of clasping are in sharp contrast, but, while a clasp on the abdomen may be characteristic of a small number of species, our observations indicate that it is not the clasp during copula.

With respect to the actual transfer of spermatophores from the genital segment of the male to that of the female, we have as yet found no account of the process for copepods of this genus, except that Wolf (1905) indicates that the transfer is direct from genital segment to genital segment, without the aid of any of the appendages.

Holmes (1909), studying the question of sex recognition, found no evidence that an odor emitted by the females played any part in the initial mating reactions; he concluded that the association of sexes in mating was due entirely to chance collisions. He placed a large number of females in a tube having one end covered with fine gauze or stopped by a small plug of cotton; when the tube was placed obliquely in water containing numerous males, these showed no tendency to gather in or about the end of the tube in which the females were confined. However, Holmes thought that olfactory stimuli may play an important rôle in causing males to remain with females longer than they otherwise would and that they may render males more prone to seize females than other males. Obviously, the fact that the clasping antennae of males possess characteristically a greater number of sense organs than do those of females, leads one to believe with Schmeil that these organs have a sexual function, although it remains to be proven that the supernumerary sense organs of males respond to chemical rather than to tactile stimuli. It will be seen later that chance collisions certainly play an important part in mating and that we were able to utilize this fact to advantage in furthering our observations.

Williams (1907) describes a single chance observation of marine harpacticid copepods where the male held the immature female and, after the molt, completed the transfer of spermatophores. He gives no details of the posture during the transfer other than in the remark that the male "moving around from the dorsal surface of the female deposited the spermatophore in its place upon the genital segment." While he was unable to repeat the observation, he concluded from indirect evidence that the premolt clasp, molting and copula are invariably associated in several species. His assumption may or may

not be correct for the marine harpacticids which came under his observation, but his further suggestion that for Crustacea in general the softened condition of the shell after a molt is a necessary condition for the attachment of spermatophores and extrusion of eggs is believed from our observations to be incorrect. It is also in conflict with the observations of Manfredi (1923) who states that a female not fecundated soon after its last molt may be fecundated a long time after, but not if she has once extruded eggs before being fecundated.

While the clasping of immature females by males has been noted by several observers, we have encountered in literature no record of the molt during the clasp and the subsequent fecundation, other than the single observation of Williams which related to marine copepods of another family and of different copulatory habit. Several observers have noted the clasping of immature females and Schmeil (1892, p. 166) believed that the immature females were fecundated. He observed impregnated females that were immature as indicated by the number of segments in the antennae. There remains however the question if the number of antenal segments is always a dependable criterion of maturity. Rehburg's observations are mentioned later in connection with *fimbriatus*.

We believe that the possibility of fecundation of immature copepods remains to be demonstrated, which can hardly be done otherwise than by observation of a female molting after actual fecundation to pass into a more advanced stage of maturity.

OBSERVATIONS

Observations of mating have been made on the following species of Cyclops: *americanus*, *bicuspidatus*, *modestus*, *serrulatus*, *prasinus*, *varicans* and *fimbriatus*.

Cyclops americanus

In the first observation on *americanus* two males held one female. One had the fourth pair of swimming feet firmly in the grip of the antennae, while the second held the female with one antenna around the first pair of swimming feet and the other extended over the posterior segments of her abdomen to pass underneath and become hooked back over the furca near its base (fig. 1). Whenever the second male would attempt to improve its hold, the first would close in against the female. Meantime a third and a fourth male made attempts to seize the female,

but these, not having gained satisfactory grips, swam away leaving the first and second still clasping the female as before described. Later, the second male, after several attempts to displace the first, gave up the attempt.

The female lay on her back somewhat obscured by the male but by rocking the dish slightly the pair could be made to lie on their sides. The genital segment of the female could then be seen plainly, and the absence of spermatophores was evident. The mating Cyclops were lying on their sides with the ventral surfaces opposed; all swimming feet of the female, except the fourth which was held by the male, were directed forward and the abdomen was curved strongly backward (fig. 2). In this posture the swimming feet of the male were about opposite

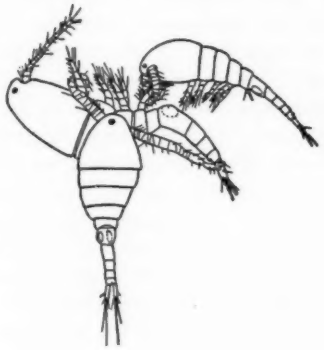

Fig. 1

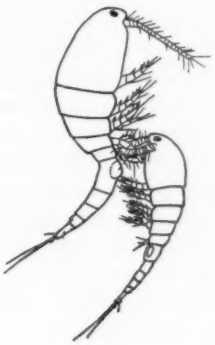

Fig. 2

FIG. 1. CYCLOPS AMERICANUS. Two males clasping a single female.
FIG. 2. CYCLOPS AMERICANUS. A mating pair in final mating position just before the transfer of spermatophores.

the genital segment of the female. The abdomen of the male was arched toward that of the female but was less sharply curved, so that the abdomens were not closely approximated. The male occasionally twitched its swimming feet in such a way as to brush the genital segment of the female. At intervals the male brought its abdomen near to that of the female by bending it strongly at the junction of the cephalothorax and abdomen. After a time the male was seen to take the spermatophores from its own genital segment with either the third or fourth pair of swimming feet and to pass them deftly to the more anterior swimming feet. The spermatophores were placed on the genital segment of the female by the anterior swimming feet. Not more than ten seconds

were consumed from the time the spermatophores were started from the genital segment of the male until they were landed on that of the female, where they were placed accurately and attached, as if by an adhesive substance. After about fifteen minutes the female was released, but she remained quiescent for two or three minutes before swimming actively away. Approximately ten minutes elapsed from the time the pair first came under observation until the transfer of spermatophores took place. The actual transfer is extremely difficult to see and Hill has observed it for this species in only four instances; ordinarily it can be seen only when the mating pair are lying in side view, and in most cases it is impossible to have this view.

The remaining eight observations of mating in *americanus* conform with the previous description in most respects. Employing both members of the pair of first antennae, the male always holds the female by the posterior swimming feet and usually only the fourth pair is held. The fourth pair of swimming feet may or may not be directed forward, depending on how the male grasps them; they may be gripped from the anterior side in such a way as to be drawn close against the mouth parts of the male as figured and described by Wolf for *fuscus*, or they may be seized from behind, and in this case they are directed forward, like the other swimming feet. For this species we have only one record where the male held the second, third and fourth pairs of swimming feet. The abdomen of the female may or may not be curved strongly backward. While the transfer of the spermatophores was observed in only four cases, the actions of the male in the remaining instances seemed to indicate that it took place in the same way each time.

Cyclops bicuspidatus.

With *bicuspidatus* the male was first seen grasping the female by the posterior swimming feet with one antenna, the other being passed underneath the furca and hooked back over it (fig. 3). The pair was then placed in a petri dish and watched under a binocular. When moved to the petri dish from the slide the male lost its grasp on the furca, regained it and lost it again some three or four times, but retained all the while the grip with one antenna on the swimming feet. Finally, giving up its hold on the furca, it grasped more firmly the second, third, and fourth pairs of swimming feet already held by one antenna, making it very difficult for the female to swim. Not once during the entire period of observation did the male loosen its grasp entirely; it held always to the swimming feet with one antenna while apparently using the grip on the

furca as a temporary means of retaining the female until a favorable opportunity occurred for completing the grasp on the swimming feet. Once the antennae of the male were tightly drawn around the swimming feet the female became very inactive except when subjected to disturbances from the outside. Approximately five minutes elapsed from the time the male effected his final hold to the moment of the transfer of the spermatophores. The relative positions of the mating pair were the same as was described for *americanus:* the ventral surfaces were opposed, but were not regularly in direct contact; the swimming feet of

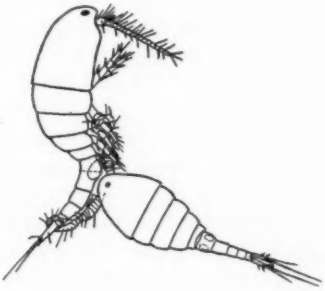

Fig. 3

Fig. 4

FIG. 3. CYCLOPS BICUSPIDATUS. Position of mating pair when first seen.
FIG. 4. CYCLOPS MODESTUS. Male clasping female by the abdomen—a premolting position.

the female were directed forward; her abdomen was curved strongly backward; the male held the three pairs of forwardly directed swimming feet of the female, its own swimming feet being directly opposite the genital segment of the female. By short, sudden, quick sweeps of its own swimming feet the male brushed the genital segment of the female, sometimes rather violently. The abdomens were not closely approximated, except when at intervals the male by strong flexure brought its abdomen forward and near to that of the female. Finally the male by a quick movement brought its genital segment near to that of

the female and the two segments appeared to be touching for not more than three seconds. Immediately afterward the spermatophores, which were not there before, could plainly be seen on the ventral surface of the genital segment of the female. The female was promptly released and both swam away. The actual transfer of spermatophores was not seen. Whether they were passed directly from the genital segment of the male to that of the female in the moment of direct contact of the two segments or were conveyed indirectly by use of the swimming feet, as in *americanus*, is not known.

Cyclops modestus.

With *modestus*, in the majority of instances, the male was first seen grasping with both antennae the abdomen of the female immediately in front of the genital segment, with its body in a position dorsal to the abdomen of the female. In this position (fig. 4) and with the abdomen bent strongly upward almost at right angles to the anterior part of the body the male allows itself to be passively carried around by the female sometimes for hours. In several instances the male held this position for more than ten hours. This is the position described by Wolf (1905) for *fimbriatus*, *phaleratus* and *affinis;* by Schmeil (1892) for *fimbriatus* and by Holmes (1909) for *fimbriatus*. However, it is not the final hold and it would seem impossible for the male to transfer spermatophores while in such a position. The grip described is used as a temporary means of retaining the female until the time arrives for grasping the swimming feet; possibly it serves also to aid the female in molting. In the majority of cases, with *modestus*, the females have molted during the mating process. We discuss this clasp further in connection with observations of *fimbriatus*.

In some collections dozens of pairs of *modestus* may be found with males gripping the immature females as described. As the molt is sloughed off the male releases it, seizes the female by the swimming feet and then completes the mating process. The female remains quiescent for a few seconds after emerging from the old molt and the male has no difficulty in grasping her. In one instance the male held on to the old molt for several minutes, carrying it around over the culture dish; but more often he releases the molt immediately to seize the newly molted female. The time required for completing the mating after the molt was never more than five minutes.

Females have been observed to molt independently of males. On the other hand, females not in the last immature stage have been seen to

molt while held by the male but in these instances no attempt was made by the male to complete the mating process.

The actions of the male during the transfer of spermatophores are very similar to those described for *americanus* and *bicuspidatus*. In every case the male held the female by the fourth pair of swimming feet and made the same movements with his swimming feet as has been described for the two preceding species.

Cyclops serrulatus.

Only four observations have been made on the mating habits of *serrulatus*. In the first instance the male grasped the female with both antennae about the fourth pair of swimming feet. The abdomens were not flexed but were separated by a considerable space. The male, seeming very inactive, held to the female while she exerted a great deal of energy dragging him around. After swimming under observation for ten minutes the female became quiescent, with swimming feet, antennae, and antennules all directed backward and body extended to become noticeably longer than normally. The molt was then seen slipping posteriorly and the fresh clear female glided from the old skin. The male retained its grasp on the fourth pair of swimming feet of the old molt until it was about half way off, he then released it and caught the female rather loosely about the third cephalothoracic segment. No sooner had the fourth pair of swimming feet emerged from the molt than the male seized them with both antennae; one swift stroke of the male hurled the old molt away. The molt gone, the work of the male was quick; in less than three minutes he had landed two light blue spermatophores on the genital segment of the female. The spermatophores were seen to pass from the genital segment of the male to that of the female by the use of the swimming feet of the former. They were taken from the genital ring of the male by either the third or fourth pair of swimming feet; in placing them upon the genital segment of the female all four pairs of swimming feet were close together, but the relatively short time taken in the transfer and the difficulty in keeping the pair in proper position for observation made it impossible to determine which pair of swimming feet played the important rôle in the transfer. Once the spermatophores touched the genital segment of the female they stuck fast and were not moved from the first position. In each of the remaining cases observed the male held the female by the fourth pair of swimming feet and occupied a position exactly as just described for the species. Molting occurred in none of these instances.

Cyclops prasinus.

Cyclops prasinus was collected in Allegany State Park, Quaker Bridge, New York. Our observations show that in the majority of cases, the male of *prasinus*, grasps the female by the fourth pair of swimming feet. He may grasp first the abdomen, furca, antennae, or any other part of the body, but if the grip is not on the posterior swimming feet the male always works around until the final hold is on the posterior swimming feet and usually on the fourth alone. The actions of the male during the transfer are just as described for *serrulatus*. The time required for the completion of the mating process varies from five to thirty minutes.

Cyclops varicans.

With *varicans* the mating pair was first seen with the male grasping the female by the fourth pair of swimming feet with both antennae. It occasionally released the female with one antenna, the left, which was passed in an apparently aimless way over the genital segment of the female. It was presumed that the transfer of spermatophores had taken place prior to the period of observation, because the female carried spermatophores when first seen. Soon the male released his grip with the right antenna and both copepods swam away. It is probable that the antennae have no function in the mating process other than as clasping organs and that the action of the left antenna of the male was merely incidental to releasing the hold on the female.

Cyclops fimbriatus.

With *fimbriatus* the grasp of the male in the process of mating has been described by Schmeil, Wolf and Holmes as being about the abdomen near the junction with the cephalothorax. The seeming impossibility of transfering spermatophores from this position, has been mentioned in connection with *modestus*. The male may take this hold at first and retain it for hours, but it is not the final grasp. The same grip on the abdomen has been observed in two instances. In the first case the male lost its hold entirely when it attempted to shift the grasp from the abdomen to the fourth pair of swimming feet. A few seconds later when he collided with the female in the water he made a second vigorous attempt to gain a grasp on the swimming feet, but the female darted quickly away. In the second instance where the male held the female

by the abdomen, the female molted after about thirty minutes; the male then shifted its grasp from the abdomen of the old molt to the fourth pair of swimming feet of the newly molted female and completed the mating process in five minutes. The swimming feet of the female were directed forward and held close against the body, the abdomen was not noticeably curved, and the female was more or less inactive. The male held the forwardly directed fourth pair of swimming feet of the female, its own swimming feet being directly opposite the genital segment of the female; its abdomen was not curved. The transfer of the spermatophores was not actually followed since the pair could not be seen in side view. The position and conduct of the mating pair were not essentially different from those observed for the preceding species. In the remaining four observations of mating in *fimbriatus* the female was held, in one instance by the fourth pair of swimming feet, in two instances by the three posterior pairs, and in the fourth case by all four pairs. Commonly only the fourth pair of swimming feet are held, it is only by accident that the more anterior feet are grasped.

As far as our observations go it is the universal habit of the males of species of Cyclops to grasp the female by the swimming feet. If one observes a mating pair without following the process to its normal finish one may be misled into the assumption that the grasp on the abdomen is the normal hold of the male in certain species. In *fimbriatus* and *modestus* the males have an evident tendency to hold immature females by the abdomen and allow themselves to be carried around for hours prior to mating. This has been given as the characteristic mating grip for *fimbriatus*, *phaleratus* and *affinis*. For *fimbriatus* and *modestus*, the only species that we have had an opportunity to observe employing the pre-molt grip about the abdomen, the final grip was found to be on the swimming feet.

Schmeil (1892, p. 166) in referring to a peculiar chitinous hook on the antennae which he describes as characteristic of males of *fimbriatus*, suggests its possible relation to the habit of the male in clasping the abdomen of the female from above, a habit he evidently assumed to be peculiar to this species—and possibly *affinis* (Schmeil, 1892, p. 22, and 159). In this connection Schmeil quotes Rehberg as reporting that females of *fimbriatus* are fecundated by mature males while the females are still immature but he adds that this is not characteristic of the species, since he has observed females of various species having receptacles filled with spermatozoa, while they were yet (as judged from the antennae) in an immature stage. However, Rehburg's observations,

although not clearly stated, seem rather to conform with ours. He says (1880) that immature females are "begattet" by mature males, but he also says that the antennae of the females change from a 7-segmented to an 8-segmented condition during "begattung," which may last 22 hours. Evidently, then, an unobserved molt occurred during the clasp, and fecundation must have taken place after the molt: Rehburg observed *clasping*, not fecundation. In such cases as have come under our observation, males have abandoned females that were not mature after the molt. Completion of the mating process by an immature female has not been observed, and, as we have previously remarked, we think the suggestion of its occurrence requires further support in direct observation.

As regards the mode of transfer of the spermatophores, all our direct observations of the actual process in several species agree in that transfer was affected by means of the swimming feet. This occasions surprise since the cyclopids are distinguished generally from the other fresh water copepods in that neither the third nor fifth feet are highly specialized for service as copulatory organs. It is possible that the lack of obvious specialization of these appendages is related not to a lack of function in transfer of spermatophores but to the distinctive form of the spermatophores in cyclopids. As matter of fact, the third swimming feet of male *Cyclops crassicaudis* do show an obvious degree of specialization in the possession of scissors-like spines on the endopodites of the third pair of swimming feet, a character which seems not to be of record for any species of Cyclops.

It may be of value now to give a short general account of mating behavior, as revised in the light of our observations.

General Account of Mating Behavior in Cyclops

Male Cyclopids have both members of the first pair of antennae modified as clasping organs and observations have revealed no other function of these appendages in the mating process other than that of holding the female, the spermatophores being transferred from the genital segment of the male to that of the female, possibly by direct contact in some cases, but also, as we have observed in several instances, by the swimming feet of the male. The spermatophores of cyclopids are quite different in form from those of copepods of other families in fresh water, being commonly compact and kidney-shaped, rather than elongate, flask-shaped and stalked as in other families of freshwater

copepods. They are attached in pairs symmetrically placed on the ventral surface of the abdomen of the female close to the opening of the seminal receptacle into which the contents of the spermatophores are soon discharged. Again, unlike the others (centropagids and harpacticids), the cyclopid males (with an exception mentioned above), have neither the third nor the fifth feet obviously modified to act as organs for the manipulation of spermatophores. Neverthelss, our observations indicate that spermatophores may actually be transferred by the use of the thoracic appendages.

Males are more active than females and show great eagerness in grasping members of their own species, or even in some cases (possibly) members of other species. On the other hand, females vary greatly in willingness to be captured by males: in a few instances they remain quiet while being seized, assuming, as Holmes says, "a condition somewhat resembling the death feint;" many, however, are very active in attempts to escape. Once seized by the male, the female finds escape practically impossible, since the male can be induced only with great difficulty to release his grasp; often he will hold even when confined beneath a coverglass or kept on a practically dry slide. Others have noted that male copepods in copula may be torn to pieces with needles without breaking the clasp of the antennae. Perhaps the positions in clasp are the resting positions of the antennal parts, as suggested by Wolf, and only a positive exertion of the male can effect release.

In all cases where we have watched the mating process of Cyclops to the finish, the male clasped the posterior swimming feet of the female with both antennae. That this should be a general rule is not in accord with the implications of previous accounts. The first grasp may be on swimming feet, abdomen, antennae or any other part of the body, but from this first hold, if not on the posterior swimming feet the male works around, often with great difficulty, to the normal mating position. During mating the swimming feet of the female are commonly directed forward and drawn close against the body, thus bringing the male, which is always the smaller member of the pair, to a position where its swimming feet are nearly opposite the genital segment of the female. The male, seemingly passive, may allow itself to be carried around by the female for some time prior to the transfer of the spermatophores. In a few cases with *americanus* the entire process was completed in ten minutes; in other instances the time consumed was thirty or forty minutes. With *modestus* males are often carried around for hours prior to the transfer of the spermatophores; in several instances the

male held the female for more than ten hours, during which time she molted, the spermatophores being transferred immediately after the molt. The actual transfer of spermatophores from the genital segment of the male to that of the female usually requires less than five seconds. Most of the time consumed in the mating process is taken by the male in overcoming the resistance of the female, in effecting his final hold, and, perhaps, in getting himself in readiness. Like Wolf, we did not observe the peculiar bending of the caudal setae of the female during the mating process, as described by Vosseler (1886).

The association of sexes seems to be due to chance collisions, as was suggested by Holmes (1909). A male Cyclops swimming in a culture dish tends to seize any Cyclops with which it may collide regardless of sex. Males may seize males of other species, but the victim in this case resists seizure effectively and darts quickly away. Such encounters between males appear often to be an expression of the combative rather than the mating instinct. We have no record for a male seizing a female of another species except with very closely related species, such as *parcus* and *americanus*, if these forms are indeed distinct species. Assuming that mating results from chance associations, the observer drew a male and a female *americanus* with a very small amount of water, into a pipette, where the pair mated immediately; the chance of collision in the tip of the pipette was of course much greater than in the culture dish. Repeated experiments of this nature were attended with success in the majority of cases, and this greatly facilitated observations, especially with females reared in culture dishes and known to be unmated.

Often more than one male grasps the same female. A second, a third, and in one case a fourth male has been seen to grasp a female already held firmly in the grip of another. After being captured by the first male and being thus greatly retarded in swimming, the female is the more readily encountered and grasped. One or more males (as many as three) may sometimes be seen tugging at a dead female, but they never persist more than a few minutes in such futile mating attempts.

Whether by design or not, males sometimes afford aid to females in the process of molting. Molting is not necessarily an immediate prerequisite to mating, although in some species, at least, mating often occurs just after the last molt of the female. When a male seizes a female about ready to molt, he apparently makes little or no effort to complete the mating process until after the molt. In such cases he has been observed to hold the old skin while the female glides out. Once the

female is out, he seizes her and completes the mating process in a few minutes. In *serrulatus* the male held the fourth pair of swimming feet while the molting was taking place but in *modestus* the male was observed in more than twenty-five cases to hold the female by the abdomen at the point of junction with the cephalothorax. After the molt the swimming feet, and not the abdomen, were grasped. As the female is relatively inactive immediately after molting, the male experiences little difficulty in regaining a proper grip.

Contrary to the accounts of previous observers we have found no instance in which the final or actual mating position was other than with the male holding the female with both antennae about the posterior swimming feet—either alone or these along with preceding pairs. Furthermore, we have found no evidence of copula with immature females or of copula while the clasp was about the abdomen.

Opinions differ as to the need for repeated matings. Wolf (1905) speaks of repeated fecundations as the rule in all families of freshwater copepods, and others have shared that view. Manfredi (1923), however, referring to several species of Cyclops, says that females are fecundated only once in a lifetime, although fertile eggs may be discharged many times during a period of months. This accords with the original statement of Jurine. Our observations on the question are inconclusive.

SUMMARY

1. There are given descriptions of the mating habits of Cyclops *americanus*, *bicuspidatus*, *modestus*, *serrulatus*, *prasinus*, *varicans* and *fimbriatus*.

2. For five of these species our observations of mating posture confirm those of previous authors in most essentials. For *fimbriatus*, the grip was found to be not as previously described but in conformity with the habit of other species of the genus.

3. The mating clasp previously supposed to be characteristic of a small group of transitional species has been observed only as a preliminary hold, generally employed where males are clinging to immature females. This clasp is used in *modestus* as well as in *fimbriatus*, although *modestus* is not regarded as one of the group of species transitional between the cyclopid and harpacticid copepod.

4. The male sometimes aids the female in effecting its last molt from an immature stage. This phenomenon, observed with *modestus*, *fimbriatus* and *serrulatus*, seems not to have been reported for freshwater

copepods. It does not appear, however, that molting must, as was suggested by Williams, be an immediate preliminary to mating.

5. Males were observed to clasp females younger than the last immature stage, but they did not attempt to complete the mating process after the molt. We cannot confirm the report of Schmeil (and others quoted by him) that immature females complete the mating process and have the receptacles filled with spermatozoa.

6. The actual transfer of spermatophores was observed: in each case at least two pairs of swimming feet and probably all four took part.

7. Mating has been induced at will by confining a male and a female in a very small amount of water where the chance of collision is greater.

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THE ECOLOGY OF THE INTERNAL PARASITES OF NIGERIAN RODENTS AND INSECTIVORES

By A. S. Pearse

While the writer was a member of the staff of the West African Yellow Fever Commission he examined a considerable number of rodents and insectivores. Post mortems were made with particular reference to organisms which might possibly be concerned with yellow fever and plague, but a careful record was kept of all parasites which were found. An account of the external parasites has already been published (Pearse, 1929); and, as this gives a general description of the country where the studies were made and the methods employed, such information will not be repeated.

Miss Sophie Dehler rendered valuable aid during the study of the parasites and the writer makes grateful acknowledgement. She studied the stained blood slides and sorted and mounted all the worms. She also nearly completed the scientific study of the tapeworms. When she was unable to continue, all the mounted cestodes were sent to Dr. C. Joyeux, University of Paris, who identified them. Dr. H. A. Baylis, of the British Museum was kind enough to study and publish an account of the nematodes (Baylis, 1928). The late Major Ingoldby of the British Museum identified the mammals. Dr. Henry Beewukis, Director of the West African Yellow Fever Commission, gave friendly cooperation throughout the work, and Mr. F. A. Bemister, Director of Education at Kano, helped in many ways while the writer was working in his province.

Between September 28 and October 31, 1926, the writer examined 300 black rats, which were obtained at the plague station in Lagos through the kindness of Drs. W. M. Allen and J. F. Paisley. The kidneys of these rodents were ground in a mortar with sterile sand and salt solution. The emulsion was then examined microscopically with dark field illumination. Each slide was studied for at least ten minutes. Organisms were found in the following percentages: non-motile bacteria, 29.4; motile bacteria, 12.3; dead spirochaetes, 0.9; motile trypanosomes, 16.0. No organisms which at all resembled the leptospiras which are

associated with Weil's disease (*Leptospira icterohaemorrhagiae*), and American yellow fever (*L. icteroides*) were observed. About 4 per cent of the rats in Lagos were infected with plague and Dr. Paisley kindly showed the writer a number of cases. No evidence of this disease was observed during the examination of the rodents and insectivores collected outside Lagos and described in this paper, though spleen smears were stained and examined in suspected cases.

NIGERIAN RODENTS AND INSECTIVORES AND THEIR ENDOPARASITES

In the following lists the number after the name of each mammal indicates the number of individuals examined. The first number after the name of a parasite indicates the percentage of individual mammals in which it occurred; the second shows the average number of parasites per individual. The totals for all species are given in table I. After the scientific name of each mammal the native names and a short description are given. The Yoruba names are in quotation marks and the Hausa names are in parenthesis. The occurrence of the parasites was as usual in mammals. The Giardias were in or near the duodenum; hexamitoids ranged more or less throughout the intestine but were usually in the rectum. Trichomonads were always in the rectum. Although trematodes occur in rodents, the writer observed none in Nigeria. Tapeworms were found in the duodenum and jejunum. Cestode cysts were scattered about among the viscera; coenuri were almost always on the outside of the intestine. Protospiruras were usually found in the stomach; other nematodes in the small intestine, except oxyurids, trichurids, and certain coprozoic species, which lived in the large intestine.

Order RODENTIA

Family MURIDAE

Subfamily Murinae

Aenomys hypoxanthus Puch., 1
"Emo," a gopher-like rodent; stout, short-tailed.

Only one specimen of this rare mouse was taken, at Ife. It contained no parasites except about 100 nematodes, *Heligmonina aenomyos* Baylis.

Arvicanthis mordax Temm., 9
"Emo" (Bera), a gopher-like rodent; stout, short-tailed; fields.

Protozoa: *Giardia* sp., 22; hexamitoids, 56; trichomonads, 33.

Cestoda: *Raillietina trapezoides* (Janicki), 56–11.7; *Raillietina* sp., 56–6.2; (total *Raillietina*, 78–18.3); coenuri, 67–2.8.

Nematoda: *Heligmonella impudica* Baylis, 100–38.1; minute rectal nematodes, 22–many.

Arvicanthis rufinus Thomas
"Emo" (Bera), a gopher-like rodent; stout, short-tailed; fields.

Protozoa: hexamitoids, 50.

Cestoda: *Hymenolepis* sp., 17–0.17; *Inermicapsifer guineensis* (Graham), 33–15.3; coenuri, 17—0.33.

Nematoda: *Heligmonella impudica* Baylis, 50–36.7; *Protospirura muricola* Gedoelst, 33–1.3; minute rectal nematodes, 17–many.

Cricetomys buchanani Thomas, 10
(Gafia, Rama), a great Gambian Rat; burrower in fields.

Protozoa: *Giardia* sp., 50; trichomonads, 100; hexamitoids, 90.

Cestoda: *Raillietina* sp., 10–0.1; *Inermicapsifer guineensis* (Graham), 100–34; coenuri, 70–9.3.

Nematoda: *Heterakis spumosa* Schneider, 20–8.2; *Heligmonina cricetomyos* Baylis, 70–15.3; *Trichuris muris*, 30–0.6; minute rectal nematodes, 10–many.

Cricetomys emini Wroughton, 18
"Okete," a great Gambian rat; burrower in forest.

Protozoa: *Giardia* sp., 22; trichomonads, 28; hexamitoids, 22.

Cestoda: *Hymenolepis* sp., 17–2.8; *Inermicapsifer guineensis* Graham, 44–11.7; peritoneal cysts, 17–0.9; hepatic cysts, 11–2; coenuri, 50–4.6.

Nematoda: *Heterakis spumosa* Schneider, 6–0.3; *Obliscoides nigeriae* Baylis, 6–0.1; *Heligmonina cricetomyos* Baylis, 89–78.3; *Protospirura muricola* Gedoelst, 50–7.7; *Physocephalus sexalatus* (Molin), 6–0.06; *Trichuris muris* (Schrank), 24–0.6.

Hybomys univittatus Pet., 44
"Epere," a striped, short-tailed, stocky, forest mouse.

Protozoa: *Giardia* sp., 23; hexamitoids, 25; trichomonads, 11.

Cestoda: *Hymenolepis pearsei* Joyeux, 39–3; *H. uncispinosa* Joyeux 32–2.8; *H.* sp., 2–0.2; *Inermicapsifer arvicanthidis* Kofend, 5–0.3; pericardial cysts, 2–0.1; pulmonary cysts, 2–0.05; hepatic cysts, 4–0.05; coenuri, 26–1.1.

Nematoda: *Porrocaecum* sp., 2–0.02; *Protospirura miricola* Gedoelst. 36–1.5; *Physaloptera aduensis* Baylis, 34–3.2; *Heligmonella* sp., 23–3.8

Leggada musculoides Temm., 47
"Iliri" (Baranyeda); a pigmy mouse; grasslands.

Protozoa: *Giardia* sp., 2; trichomonads, 8; hexamitoids, 26.
Cestoda: Coenuri, 2–0.02.
Nematoda: *Heligmonella gracilis* Baylis, 28–3.3; *Heligmonina murina* Baylis, 30–6.7; *Protospirura muris* (Ginelin), 6–0.06; *Protospirura muricola* Gedoelst, 4–0.06; oxyurid, 6–1; minute rectal nematodes, 2–many.
Unknown cysts: hepatic, 4–0.06; on intestine, 15–6.

Lemniscomys striatus L., 22
"Ago," a striped ground squirrel; fields.

Protozoa: Amoebas, 5; *Giardia* sp., 5; trichomonads, 5; hexamitoids, 45.
Cestoda: *Inermicapsifer arvicanthidis* Kofend, 23–0.4; *Raillietina trapezoides* (Janicki), 9–1.4; hepatic cysts, 9–5.7; intestinal coenuri, 18–0.2; cardiac coenuri, 5–0.09.
Nematoda: *Syphacia nigeriana* Baylis, 9–3.3; *Heligmonella impudica* Baylis and *H. intermedia* Baylis, 100–85.6; *Protospirura muricola* Gedoelst, 23–0.9; *Trichuris muris* (Schrank), 5–0.05; minute rectal nematodes, 9–many.

Lophuromys sikapusi Temm., 11
"Olubrikotu;" field mouse.

Protozoa: Amoebas, 18; *Giardia* sp., 9; trichomonads, 18; hexamitoids, 9.
Cestoda: Unknown tapeworm, 9–0.09; coenuri, 64–1.7.
Nematoda: *Porrocaecum* sp., 9–0.09; *Heterakis spumosa* Schneider, 9–0.09; *Subulura boueti* (Gendre), 9–0.09; *Heligmonella* sp., 45–5.5; minute rectal nematodes, 9–many.

Malacomys edwardesi Rochebr., 19
"Agasha;" slender, long-tailed, forest mouse.

Protozoa: *Giardia* sp., 16; trichomonads, 5; hexamitoids, 16.
Cestoda: *Hymenolepis* sp., 27–1.9; *Raillietina baeri* Meggitt and

Subramanian, 16–0.3; cardiac cysts, 5–0.05; hepatic cysts, 21–0.5; coenuri, 79–3.5.

Nematoda: *Heligmonella monnigi* Baylis and *Heligmonina praomys* Baylis, 79–31.7; *Protospirura muricola* Gedoelst, 16–0.9.

Mastomys erythroleucus Temm., 31
"Edayeda;" field rat.

Protozoa: Amoebas, 6; *Giardia* sp., 3; trichomonads, 6; hexamitoids, 61.

Cestoda: *Catenotaenia lobata* Baer, 13–1.2; *Hymenolepis uncispinosa* Joyeux, 16–0.8; *Inermicapsifer arvicanthidis* Kofend, 3–0.3; *Raillietina baeri* Meggitt and Subramanian, 16–1.9; hepatic cysts, 20–12.3; coenuri, 52–2.2.

Nematoda: *Syphacia nigeriana* Baylis, 13–2.3; *Heligmonella affinis*, 71–15.6; *Protospirura muricola* Gedoelst, 9–0.4; *Trichuris muris* (Schrank), 20–0.6, minute rectal nematodes, 9–many.

Mastomys sp., 4
"Edayeda;" field rat.

Protozoa: Hexamitoids, 50.

Cestoda: *Raillietina baeri* Meggitt and Subramanian, 75–1.3; coenuri, 75–1.5.

Nematoda: *Syphacia nigeriana* Baylis, 25–12.5; *Heligmonella* sp., 75–8.5; *Trichuris muria* Gedoelst, 25–0.8.

Mus musculus L., 3
"Olo;" house mouse.

Cestoda: Intestinal cysts, 33–0.3; coenuri, 33–0.3.

Nematoda: *Heligmonoides murina* Baylis, 33–1; *Protospirura muricola* Gedoelst, 33–0.7.

Praomys tullbergi Thomas, 96
"Eda;" common forest mouse.

Protozoa: Amoebas, 4; *Giardia* sp., 1; trichomonads, 5; hexamitoids, 20.

Cestoda: *Raillietina baeri* Meggitt and Subramanian, 7–0.3; gastric cysts, 1–0.01; peritoneal cysts, 3–0.05; hepatic cysts, 20–0.4; coenuri, 53–2.

Nematoda: *Subulura boueti* (Gendre), 2–0.02; *Syphacia nigeriana* Baylis, 23–6.5; *Heligmonella monnigi* Baylis and *Heligmonina praomys* Baylis, 87–59.3; *Protospirura muricola* Gedoelst, 66–2.5; *Trichuris muris* (Schrank), 66–2.5; *Capillaria pearsei* Baylis, 14–0.8; minute rectal nematodes, 2–many.

Rattus rattus L., 79
"Akuile;" black rat.

Protozoa: Amoebas, 5; *Giardia* sp., 4; trichomonads, 7; hexamitoids, 25; *Trypanosoma lewisi* Kent, 23.

Cestoda: *Hymenolepis* sp., 4–0.3; *Taenia taeniaeformis* Bartsch, cysticeri (rectal, 1–0.01; renal, 1–0.01; hepatic, 36–0.7), 40–0.7; coenuri, 49–2.1.

Nematoda: *Heligmonella* sp., 3–0.1; *Protospirura muricola* Gedoelst, 5–0.08; minute rectal nematodes, 4–many.

Uranomys foxi Thomas, 1
Field mouse.

Protozoa: Hexamitoids, 100.

Nematoda: *Heligmonella* sp., 100–24; *Protospirura muricola* Gedoelst, 100–0.2.

Subfamily Gerbillinae

Taterillus gracilis angelus Thomas, 9
(Berrandagi); jerboa.

Protozoa: Hexamitoids, 44.

Cestoda: Unknown tapeworm, 11–1.3; coenuri, 44–2.1.

Nematoda: *Syphacia nigeriana* Baylis, 44–8; *Rictularia taterilli* Baylis, 44–1.2; unknown strongylid, 11–1.1; cysts in mesentery, 22–36.8; minute rectal nematodes, 11–many.

Taterona kempi Wroughton, 25
"Afe;" short-tailed field rodent.

Protozoa: Amoebas, 12; *Giardia* sp., 4; trichomonads, 24; hexamitoids, 76.

Cestoda: *Catenotaenia lobata* Baer, 60–14.8; *Hymenolepis* sp., 28–1.8; *Raillietina trapezoides* (Janicki), 4–0.08; *Inermicapsifer arvicanthidis* (Kofend), 4–0.2; hepatic cysts, 28–14.9; coenuri, 24–1.

Nematoda: *Syphacia nigeriana* Baylis, 4–17.9; *Parastrongylus tateronae* Baylis, 4–1.9; *Heligmonella impudica* Baylis, 68–40; *Protospirura muricola* Gedoelst, 100–20; *Trichuris muris* (Schrank), 60–1.7; Filaria larvae, 4–many; minute rectal nematodes, 24–many.

Family LEPORIDAE

Lepus zechi Matsch, 2
"*Ehoro*;" rabbit in guinea grass.

Cestoda: Hepatic cysts, 50–2.
Nematoda: *Heligmonella* sp., 50–5.

Family THRYNOMYIDAE

Thrynomys swinderianus Temm., 1
"Oya;" large, short-tailed, "cut grass."

Nematoda: *Heligmonella spira*, 100–120.

Family SCIURIDAE

Euxerus erythropus moestus Thomas, 2
"Ikun;" tree squirrel.

Protozoa: Hexamitoids, 50.
Cestoda: Hepatic cysts, 50–200.
Nematoda: *Syphacia* sp., 50–100; *Protospirura muricola* Gedoelst, 50–1.

Funisciurus anerythrus Thomas, 12
"Okere;" common tree squirrel.

Protozoa: Amoebas, 8; hexamitoids, 17.
Cestoda: *Raillietina baeri* Meggitt and Subramanian, 8–0.17; hepatic cysts, 8–0.08; intestinal cysts, 8–0.25; coenuri, 33–1.2.
Nematoda: *Heligmonella streptocera* Baylis and *H. trifurcata* Baylis, 100–34; *Protospirura muricola* Gedoelst, 58–5.2; *Trichuris muris* (Schrank), 33–5.2.

Funisciurus auriculatus oliviae Dollman, 5
"Okere-adaripon;" red-capped tree squirrel.

Cestoda: *Hymenolepis* sp., 20–0.4; gastric cyst, 20–0.2; pulmonary cyst, 20–0.2; hepatic cysts, 40–13.6.

Nematoda: *Protospirura muricola* Gedoelst, 40–2.4; *Capillaria pearsei* Baylis, 40–7; *Heligmonella* sp., 100–82.6.

Heliosciurus isabellinus Gr., 3
"Ase;" tree squirrel.

Nematoda: *Syphacia pearsei* Baylis, 33–16.7; *Protospirura muricola* Gedoelst 33–2; *Heligmonella* sp., 33–1.

Protoxerus stangeri nigeriae Thomas, 1
"Odugbo;" giant tree squirrel.

Nematoda: *Heligmonina magna* Baylis, 100–3.

Order INSECTIVORA

Family ERINACEAE

Atelerix spiculus Thomas and Wroughton, 5
"Lili" (Bushea); hedgehog.

Protozoa: Hexamitoids, 20.
Cestoda: *Oochoristica herpestis* Kofend, 80–12.8.
Nematoda: *Physaloptera dispar* von Linstow, 80–8.8.

Atelerix spinifex Thomas, 2
"Lili" (Bushea); hedgehog.

Cestoda: *Oochorista herpestis* Kofend, 50–1.5; peritoneal cysts, 100–19.
Nematoda: *Physaloptera dispar* von Linstow, 100–64.

Family SORICIDAE

Crocidura manni Pet., 18
"Asin" (Jaba); shrew.

Cestoda: *Hymenolepis* sp., 78–44.2; *H. scalaris* (Dujardin), 6–0.3; peritoneal cysts, 44–16.1; coenuri, 11–1.3.
Nematoda: *Physaloptera* sp., 22–1.9; *Heligmonella* sp., 6–0.2.

Crocidura sp., 15.
"Asin;" shrew.

Cestoda: *Hymenolepis scalaris* (Dujardin), 40–1.6; *Hymenolepis* sp., 7–0.07.

Nematoda: *Porrocaecum* sp., 13–0.27; *Physaloptera* sp., 20–0.8; minute rectal nematodes, 7–many.

The results for all species are summarized in table I. The minute nematodes which often occurred in the rectum are not included in this table for two reasons: (1) they could not be counted because they were so active and numerous and (2) they were probably coprophagic and therefore not significant in a study of parasitism. They were present in 12 of the 29 mammals studied; one of these was a shrew and remainder were rodents. They were never found in arboreal species and were most common in those living on the ground in dry open fields.

In insectivores protozoa and strongylid nematodes were rare and cestode cysts were less common than in rodents, but tapeworms and the nematodes which probably enter the host through the mouth with the food, rather than through the skin, were of much more frequent occurrence.

If one attempts to determine the factors which influence the distribution of the entozoa in the twenty-nine species of small mammals studied by scrutinizing the figures in table I, he is lost in a maze. For example the mammal which contains the largest number of protozoa is the giant, burrowing steppe rat (*Cricetomys buchanani*, 240); next is a medium sized rat (*Taterona kempi*, 116), from the savanna and rain forest; then a guinea-pig-like rodent from the desert (*Arvicanthis mordax*, 111); a rare mouse from the guinea grass (*Uranomys foxi*, 100); a large mouse from the forest and guinea grass (*Mastomys erythroleucus*, 76); a giant, burrowing rat from the wet, coastal forest (*Cricetomys emini*, 72); the black house rat (*Rattus rattus*, 64); a striped ground squirrel (*Lemniscomys striatus*, 60); a short-tailed, striped forest mouse (*Hybomys univittatus*, 59); etc. Seven species of rodents and three of insectivores contained no protozoa; nine rodents were without tapeworms; six rodents and one shrew contained no cestode cysts; five rodents had no nematodes which probably enter through the mouth with the food; and two hedgehogs, a shrew, and a tree squirrel were without strongylids. The writer attempted to find some general principles by arranging the figures in various orders with reference to various factors and met with very little success. Other types of comparisons were therefore made. There is some indication that parasites are more common in the commonest and largest hosts, in those which have a wide range of habitats and live largely on the surface of the soil, but the evidence is not very satisfying.

TABLE I

OCCURRENCE OF PARASITES IN VARIOUS MAMMALS

The first figure in the columns under parasites shows the total of the percentages of mammals which contained parasites; the second indicates the number of parasites per individual. Lengths are given in millimeters; the first is from tip of nose to middle of anus; the second, from anus to tip of tail. "Mouth" and "skin" are short terms which refer to nematodes other than strongylids and strongylids respectively.

	LENGTH	PROTOZOA	CESTODA		NEMATODA		TOTALS
			Tapes	Cysts	Mouth	Skin	
Aenomys hypoxanthus	170–175	0	0	0	0	100–100.0	100–100.0
Arvicanthis mordax	147–116	111	78–18.3	67–2.8	0	100–38.1	358–61.2
Arvicanthis rufinus	159–136	50	50–15.5	17–0.3	33–1.3	50–36.7	200–73.8
Atelerix spiculus	175–20	20	80–12.8	0	80–8.8	0	180–31.6
Atelerix spinifex	176–31	0	50–1.5	100–19.1	100–64.0	0	250–84.5
Cricetomys buchanani	346–377	240	110–34.1	70–9.3	50–8.8	70–15.3	540–67.5
Cricetomys emini	310–343	72	61–14.5	78–7.5	87–8.8	89–78.3	387–109.1
Crocidura manni	141–87	0	84–44.5	55–17.4	22–1.9	6–0.2	167–64.0
Crocidura sp.	101–68	0	47–1.7	0	33–1.1	0	80–2.8
Euxerus erthropus moestus	314–208	50	0	50–200.0	100–101.0	0	200–301.0
Funisciurus anerythrus	179–146	25	8–0.2	49–1.5	93–10.4	100–34.0	275–46.1
Funisciurus auriculatus oliviae	208–172	0	20–0.4	80–14.0	80–9.4	100–82.6	280–106.4
Heliosciurus isabellinus	215–237	0	0	0	67–18.7	33–1.0	100–19.7
Hybomys univittatus	115–95	59	78–6.3	34–1.3	72–4.7	23–3.8	266–16.1
Leggada musculoides	67–35	36	0	2–+	16–1.1	58–10.0	112–11.1
Lemniscomys striatus	111–122	60	32–1.8	32–6.0	37–4.3	100–85.6	261–97.7
Lepus zechi	425–62	0	0	50–2.0	0	50–5.0	100–52.0
Lophuromys sikapusi	120–66	54	9–0.1	64–1.7	27–0.3	45–5.5	199–7.6
Malacomys edwardesi	121–147	37	43–2.2	105–4.1	16–0.9	79–31.7	280–38.9
Mastomys erythroleucus	119–108	76	48–4.2	72–14.5	42–3.3	71–15.6	309–37.6

Mastomys sp.	123–117	50	75–1.3	75–1.5	50–13.3	75–8.5	325–24.6
Mus musculus	75–80	0	0	67–0.6	33–0.7	33–1.0	133–2.3
Praomys tullbergi	108–127	30	7–0.3	74–2.5	171–12.5	87–59.3	375–74.6
Protoxerus stangeri nigeriae	290–300	0	0	0	0	100–3.0	100–3.0
Rattus rattus	158–176	64	4–0.3	89–2.8	5—0.1	3–0.1	165–3.3
Taterillus gracilis angelus	111–137	44	11–1.3	44–2.1	88–2.0	11–1.1	198–6.5
Taterona kempi	162–156	116	96–16.9	52–15.9	208–39.6	72–41.9	544–114.3
Thrynomys swinderianus	500–196	0	0	0	0	100–120.0	100–120.0
Uranomys fozi	100–48	100	0	0	100–2.0	100–24.0	300–26.0
General average	207–141	45	36–6.1	46–11.3	59–11.0	55–27.7	237–58.0
Insectivore average	148–77	5	65–15.1	39–9.1	239–19.0	2–0.1	169–45.7

ENTOZOA AND CLIMATE

As has been explained in detail in a previous paper (Pearse, 1929), the climates of the four localities in Nigeria where collections were made

TABLE II

AVERAGE INFECTION WITH VARIOUS TYPES OF PARASITES AT FOUR LOCALITIES: LAGOS, WET PALM FOREST; IFE, RAIN FOREST; IBADAN, SAVANNA; KANO, STEPPE-DESERT

The first figure indicates average percentage of mammals infested; the second, shows number of parasites per individual.

	LAGOS	IFE	IBADAN	KANO
Amoebas	4–	5–	6–	0
Hexamitoids	20–	26–	26–	27–
Trichomonads	7–	20–	5–	15–
Giardias	4–	11–	2–	8–
Trypanosomes	1.2–	0	0	0
Total protozoa	36.2–	66–	39–	50–
Unknown cestode	0	0	0	1–0.15
Inermicapsifer	3–0.77	0	3–1.3	11–3.8
Oochoristica	0	0	0	15–1.6
Raillietina	3.5–0.15	40–7.2	4–0.33	10–2.0
Hymenolepis	11–1.1	5–0.7	18–2.2	11–5.7
Catenotaenia	1.7–0.07	4–0.3	6–1.3	0
Cestode cysts	13–17.1	24–14.0	21–7.5	14–2.4
Coenuri	27–1.12	40–1.0	16–2.5	29–14.2
Total cestodes	59.2–20.31	113–23.21	68–15.13	91–29.85
Ascaridae	2–0.03	0	0	0
Heterakidae	0.1–0.001	10–0.6	0	2–0.7
Oxyuridae	9–7.6	10–1.7	7–1.5	5–0.7
Metastrongylidae	0	0	3–0.15	0
Trichostrongylidae	57–51.6	76–23.8	56–21.6	20–5.8
Spiruridae	27–1.7	0	41–2.9	14–8.4
Trichinellidae	12–1.0	5–0.2	7–0.2	3–0.1
Filarial larvae	0	0	4–0.3	
Unknown nemas	0	0	0	1–0.12
Nematode cysts	0	0	0	2–4.1
Minute rectal nemas	1.8–	0	7–	7–
Total nematodes	108.9–61.93	101–26.30	118.6–26.35	54–19.92
Grand total	204.3–82.24	276–49.51	225.6–41.48	195–49.77

by the writer differ considerably: (1) Lagos is on the sea coast in a wet forest and has an annual rainfall of 72 inches; (2) Ife is about 150

miles inland in the edge of a rain forest and has an annual rainfall of 57 inches, (3) Ibadan is in the savanna, where the guinea grass stands 15 feet high, and has a rainfall of about 49 inches; and (4) Kano is in a steppe-desert where the rainfall is 34 inches. The mean annual temperatures of the four localities differ very little, being respectively 81.1°, 79.7°, 80.8°, and 80°F. In table II the statistics have been arranged so that they fall under four headings, according to the climates in which the parasites were collected.

At Lagos, in the wet palm forest, there were fewest protozoa and fewest tapeworms, but many mammals were infested with all types of nematodes (the ascarids were all found there) and there was the largest total number of parasites per individual (82.24).

At Ife, in the edge of the rain forest, the most protozoa occurred. There was also the highest number of tapeworms per individual (8.2), and the highest number of animals infested with non-strongylid tapeworms. No *Spiruridae* were found.

At Ibadan, in the guinea grass, there were fewest cestode cysts and not many protozoa. Most mammals (97) were infested with strongylids and many with other nematodes.

At Kano, in the steppe-desert no amoebas were found. Most animals there were infested with tapeworms and cestode cysts, and the largest number (44.1) of the latter per individual occurred. However, there were fewest animals with nematodes and the lowest number of strongylids per individual.

On the whole parasites decrease in number as the climate becomes drier. This is largely due to the decrease in nematodes, the eggs of which are apparently not able to stand desiccation. On the other hand cestode cysts and to some extent tapeworms also, become more abundant in dry climates, though they are fewest in the guinea grass.

ENTOZOA AND HOST HABITATS

The insectivores and rodents show segregation into various habitats and for purposes of comparison the 25 species on which the writer has adequate data may be divided into four groups. Those which live in trees are compared with those which live on the surface of the ground; those in the forest with those which frequent grass lands or cultivated fields. Table III shows that there are 20 ground species, 5 arboreal (all squirrels), 13 campestrine, and 12 sylvan.

Most protozoa occur on ground mammals (54) and very few (12) in

arboreal species. No trichomonads or giardias were found in any of the five species of tree squirrels. More protozoa occurred in animals which lived in open fields (49) than in those in the forest (32).

TABLE III

COMPARISON OF PARASITES IN MAMMALS WHICH LIVE ON SURFACE OF GROUND AND IN TREES; IN FIELDS AND IN FORESTS

The first figure indicates the average percentage of mammals infested; the second, the number of parasites per individual.

	GROUND, 20	TREES, 5	FIELDS, 13	FOREST, 12
Amoebas	2–	2–	2–	2–
Hexamitoids	32–	10–	34–	19–
Trichomonads	12–	0	15–	6–
Giardias	8–	0	7–	5–
Total Protozoa	54–	12–	9–	32–
Inermicapsifer	11–3.1	0	13–3.9	4–1.0
Oochoristica	6.5–0.7	0	10–1.1	0
Raillietina	11–1.2	2–0.08	15–1.8	3–0.06
Hymenolepis	14–3.0	4–0.1	9–3.6	13–1.1
Catenotaenia	4–0.8	0	6–1.2	0
Unknown cestode	0.5–0.005	0	1–0.01	0
Cestode cysts	16–3.7	22–42.9	19–4.7	15–22.5
Coenuri	31–1.6	7–0.2	29–1.6	20–1.0
Total Cestoda	94–14.11	35–43.28	102–17.7	55–25.66
Ascaridae	2–0.03	0	1–0.01	2–0.03
Heterakidae	2–0.45	0	3–0.6	1–0.04
Oxyuridae	6–2.2	17–23.3	7–2.9	5–1.8
Metastrongylidae	0.2–1.0	0	0.3–0.1	0
Trichostrongylidae	62–33.9	67–25.1	51–17.3	76–33.9
Spiruridae	33–5.8	36–2.1	29–7.4	35–2.5
Trichinellidae	12–0.35	15–2.4	11–0.3	14–1.3
Filarial larvae	0.2–	0	0.3–	0
Rectal nematodes	6–	0	8–	1–
Nematode cysts	1–0.4	0	1–0.5	0
Total Nematoda	124–44.07	135–52.9	112–29.11	134–39.54
Grand Total	271–58.18	182–96.18	264–47.01	219–65.20

Tapeworms were rare in arboreal species but cestode cysts at times were very numerous in particular individuals. Nearly three times as many mammals were infested with tapeworms in fields as were in forests;

and eight times as many on the ground as in trees. Cestode cysts were most frequently present in animals in fields (48) and in animals on the ground (47) compared to those in trees (29); but the greatest number of parasites per host occurred in arboreal (43.1) and sylvan (23.5) species.

Nematodes are most abundant in arboreal animals probably because shade and moisture in forests are favorable for the development of the eggs and because when the hosts visit the ground they go again and again to situations which are favorable for infection. There are more nematodes in forest animals than in those in open fields. This is due more to strongylids than to other nematodes, which are somewhat more common in fields and much more numerous in individual hosts on the ground than in those in trees.

The five species of tree squirrels are of particular interest because of their differences in degree of adaptation to arboreal life. For this reason the ratio between body-length and tail-length has been computed and the writer has arranged the species in order according to their degree of association with the surface of the ground. For example, *Euxerus erythropus moestus* is often seen on the ground and is a great pest in the fields of the natives, from which it steals peanuts and other products, and *Protoxerus stangeri nigeriae* seldom leaves the tops of the highest trees in the rain forest. In the following list the body length and tail length ratio are given in parenthesis immediately after the name of the squirrel and the total number of individual mammals infested and total average number of parasites per individual are last:

Euxerus erythropus moestus, (1:0.66); 200–301.
Funisciurus anerythrus, (1:0.81); 275–45.6.
Funisciurus auriculatus oliviae, (1:0.83); 280–93.1.
Heliosciurus isabellinus, (1:1.10); 100–18.8.
Protoxerus stangeri nigeriae, (1:1.03); 100–3.

The last two species are rather strictly arboreal, but the first three are often seen on the ground and in this respect there is very little difference between the second and third species. The strictly arboreal species have considerably fewer parasites than those which are more terrestrial.

Considering all types of parasites, mammals which live on the ground and in fields are more often infested than those in forests, but the occurrence of large numbers of oxyurids, strongylids, and cestode cysts brings the total number of parasites per individual higher in tree squirrels than in other forest rodents or in small mammals which live in

open fields. There are also more parasites per individual host in forests than in fields. Nematodes are apparently dependent more or less on moisture and vegetation.

ENTOZOA AND FOOD

Careful records were kept of the enteric contents of all animals examined and the lengths of intestines were examined in many instances, but sometimes the character of the food could not be certainly determined and often there was no food. After the field observations had been completed the writer realized that he had not measured enough

TABLE IV

INSECTS IN FOOD IN RELATION TO PARASITES

The amount (estimated percentage of volume) occurring is given after each name; figures in parenthesis indicate length of intestine in relation to body length. Computation was made from the following animals: (1) *Atelerix spiculus*, 100 (4.21); *Crocidura* sp., 93 (4.60); *Crocidura manni*, 54 (2.76); *Hybomys univittatus*, 44 (6.42); *Taterona kempi*, 40 (5.41); *Leggada musculoides*, 28 (3.75); (2) *Praomys tullbergi* 24 (5.09); *Lemniscomys striatus*, 20 (4.06); *Atelerix spinifex*, 20; *Malacomys edwardesi*, 18 (6.50); *Lophuromys sikapusi*, 14 (5.78); *Arvicanthis rufinus*, 13; *Rattus rattus*, 11 (4.65); *Taterillus gracilis angelus*, 5 (4.91); *Arvicanthis mordax*, 5; *Cricetomys buchanani*, 0; *C. emini*, 0; *Funisciurus anerythrus*, 0 (7.70); *F. auriculatus oliviae*, 0; *Heliosciurus isabellinus*, 0; *Lepus zechi*, 0; *Protoxerus stangeri nigeriae*, 0; *Thrynomys swinderianus*, 0 (6.53).

	NUMBER	LENGTH OF INTESTINE	PROTOZOA	CESTODA		NEMATODA		TOTAL
				Tapes	Cysts	Mouth	Skin	
25% of insects.....	6	4.53	39	64-23.7	21-5.6	73-9.9	26-9.0	223-48.2
Less than 25% of insects.....	18	5.56	34	31-5.2	54-5.0	57-8.6	65-34.0	241-52.8

intestines. The two foods occurring in largest quantity were vegetation and insects. Records of food were obtained from 25 species of rodents and insectivores. The average percentages for all these species are as follows:—vertebrates, 2.4; insects, 24.8; vegetation, 24.4; beans, 0.7; cassava, 11.2; corn, 10.6; peanuts, 1.7; palm nuts, 19.5; unknown seeds, 1.3; sand, 0.1; unknown, 4.7. Insects and vertebrates constitute 27.2 per cent of the food and all vegetation about 68 per cent.

In table IV the parasites of hosts which eat a considerable quantity of insects are compared with those of hosts which do not. Insect-eaters have slightly more of protozoa and non-strongyloid nematodes. They

have decidedly more tapeworms. The non-insect eaters contain many more strongylid nematodes and this gives them a slight preponderance of total parasites. Tapeworm cysts occur most often in them but the insect-eating group contains more of these parasites per individual host.

In table V the parasites of mammals which eat large amounts of vegetation are compared with those which do not. Vegetarians show a decided preponderance of protozoa, nematodes, and total parasites. There are many more tapeworms in non-vegetarians. Cestode cysts are again not clearly aligned with either group.

TABLE V

VEGETATION IN FOOD IN ITS RELATION TO PARASITES

The amount (estimated percentage of volume) of vegetation occurring is given after each name; figures in parentheses indicate length of intestine in relation to body length. Computation was made from the following animals: (1) *Funisciurus anerythrus*, 100 (7.70); *F. auriculatus oliviae*, 100; *Cricetomys buchanani*, 100; *C. emini*, 100; *Thrynomys swinderianus*, 100 (6.53); *Lepus zechi*, 99; *Taterillus gracilis angelus*, 95; *Arvicanthis mordax*, 95; *Rattus rattus*, 85 (4.65); *Arvicanthis rufinus*, 82; *Atelerix spinifex*, 80; *Protoxerus stangeri nigeriae*, 80; *Lophuromys sikapusi*, 76 (5.78); *Leggada musculoides*, 70 (3.75); *Praomys tullbergi*, 70 (5.09); *Lemniscomys striatus*, 66 (4.06); *Mastomys erythroleucus*, 66 (4.84); *Malacomys edwardesi*, 58 (6.50); *Hybomys univittatus*, 52 (6.42); *Taterona kempi*, 50 (5.41); (2) *Crocidura manni*, 3 (2.76); *Crocidura* sp., 3 (4.60); *Atelerix spiculus*, 0 (4.21).

	NUMBER	LENGTH OF INTESTINE	PROTOZOA	CESTODA		NEMATODA		TOTAL
				Tapes	Cysts	Mouth	Skin	
50% of vegetation.....	21	5.30	51	33–5.6	5–5.1	53–9.1	63–31.7	205–51.5
Less than 50% of vegetation.....	3	3.86	7	70–23.0	3–5.8	45–3.9	2–0.1	127–32.8

These results appear to indicate that nematode parasites and protozoa which do not enter small mammals through the skin gain access to their hosts with food plants and that tapeworms are associated with insects, and that cestode cysts are not particularly associated with either plants or insects as foods. Hegner (1924) has shown that, if rats are fed on a strictly meat diet, protozoa do not occur in the intestine and he believes this to be due to the bacterial flora present.

CONCLUSIONS

The parasites of 29 species of small mammals (25 rodents; 4 insectivores) were studied in Nigeria in four localities which were typical

examples of wet palm forest, rain forest, savanna, and steppe-desert. Protozoa and strongylid nematodes were rare in insectivores and cestode cysts were less common than in rodents, but tapeworms and the types of nematodes which usually enter the host through the mouth with the food rather than through the skin, were of much more frequent occurrence. On the whole parasites became fewer toward the desert as the climate grew drier. This was largely due to the decrease in nematodes. Cestode cysts, and to some extent tapeworms, became more abundant in the driest climates, though they were fewest in the savanna.

Parasites showed rather definite relations to the habitats of hosts. Considering all types of parasites, mammals which live on the ground in open fields were more often infested, but the occurrence of large numbers of nematodes and cestode cysts in certain species made the total number of parasites per individual higher in tree squirrels than in other forest rodents or in the small mammals of open fields. Nematodes apparently depend on moisture and vegetation in the environment. There were more parasites per individual host in forests than in fields. Apparently nematodes and protozoa which do not enter their hosts through the skin gain access through the mouth with food plants. Tapeworms are often associated with a high percentage of insect foods, but immature cestodes are not.

The small arboreal mammal which has fewest parasites subsists on plants and does not go down to the ground. One which lives on the surface of the ground and has few parasites is a vegetarian in a dry climate. The rodent which may be expected to have most parasites is large, eats both insect and plant foods, and lives on the ground among luxuriant vegetation in a climate that is not too wet or too dry.

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FURTHER OBSERVATIONS ON ASCIDIAN BLOOD[1]

By W. C. George

Plate 29

During the summer of 1927 I continued my observations on the histology of ascidian blood. The forms studied were *Phallusia hygomiana* Traustedt and *Styela plicata* Lesueur. Both of these species are common at Beaufort attached to the bridge and wharf piles. Both are large enough to handle conveniently, and the blood may be easily withdrawn from the heart through a hypodermic needle after the test has been peeled away, though in the case of *Styela* it is necessary to split the mantle as well in order to see the heart.

As in my previous studies fixed and sectioned material was used to supplement the studies of fresh blood stained with vital stains and treated with various reagents. The sectioned material did not reveal any additional types of cells. A sea water solution of the vital stains may be applied to a cover glass preparation of fresh blood or the blood may be examined after the animal has been immersed for some hours in a sea water solution of the stain.

The following types of cells are distinguishable in the fresh blood:

Phallusia hygomiana

1. Green cells, slightly amoeboid. These cells are not essentially different in appearance from the green cells previously described and figured (see George '26) for *Perophora viridis*. Green colored fatty globules fill the cell except for the space occupied by the nucleus. The cytoplasm in which they are embedded is colorless. The globules are not solid fat but have a fatty rim. The appearance after fixation with ammonia (which changes the color of the cells from bright green to

[1] This investigation was aided by a grant from the Rockefeller Foundation for Research. It was carried on at the Beaufort laboratory of the U. S. Bureau of Fisheries. I wish to express my appreciation to the Commissioner, Hon. Henry O'Malley, for the privilege of working at the station and to the Director of the station, Dr. Samuel F. Hildebrand, for his kindness and assistance during the course of the investigation.

brownish yellow) indicated that this rim is made up of granules. The granules blacken with osmic acid but I have not succeeded in getting them to stain with Sudan III or Sharlach R. They stain with the basic vital stains such as methylene blue and neutral red, the globules in some cells staining more readily than in others. Janus green B (1:100,000 solution in sea water) gives the green globules a pale bluish cast.

Henze ('11, '12) has shown that the plasma of ascidian blood is alkaline in reaction while the cells are strongly acid, containing according to Henze about three per cent of free sulphuric acid. I have observed certain reactions of the cells to eosin which indicates that the acid is contained principally in the green globules. Hydrochloric acid precipitates an aqueous solution of eosin. I have observed that when eosin in sea water is run under a cover glass with fresh blood until the fluid is given a pinkish tinge there is no immediate precipitation of the stain, the fluid being alkaline, nor do the cells stain. The cells remain alive in such a solution for a considerable time—I have seen colorless blood cells undergoing amoeboid activity for as long as an hour. The alkaline plasma allows the eosin to remain in solution and the surface membranes of the living cells, being apparently virtually impermeable to eosin, protects the cytoplasm from the stain. By and by the cells die and take the stain—the colorless cells first, the green cells later. Upon the death of the green cells the eosin is precipitated around them forming a sort of halo of eosin granules. The precipitation of the stain is due no doubt to the outward diffusion of the sulphuric acid contained in the cells. Precipitation of the stain around other types of cells is not noticeable. Furthermore if we run a solution of eosin under a cover glass preparation of blood that has stood until the cells are dead there is at once a general precipitation of the stain throughout the plasma but the precipitation appears to be somewhat greater immediately around the green cells. The diffusion of acid from the dead cells has rendered the plasma acid throughout but more strongly so in the vicinity of the source of the acid.

2. Orange cells like those previously described and figured for *Perophora viridis* have orange colored globular masses filling the cell body. The cytoplasm in which they are embedded is clear and colorless. The orange masses do not blacken with osmic acid nor do they stain with any of the stains that I have used. These cells are present in small numbers in the blood channels but they are most numerous in the tissue of the mantle around the siphons.

3. Vacuolated cells (figs. 1 and 2) in which the vacuoles appear turgid. They are apparently homologs of the "colorless morula cells" of *Perophora*. In a cover glass preparation of unstained living blood these cells are difficult to distinguish from the "compartment cells." They do not blacken with osmic acid, though they assume a light blue-gray color. They are strongly eosinophilic at times, and they take on a blue color upon treatment with Janus green B.

4. Coarsely granular amoeboid cells (fig. 3) similar to those that I have previously described for other species. The colorless cytoplasm contains numerous coarse colorless granules most of which do not blacken with osmic acid, though some may. These cells average somewhat larger in size than the other cell types. The relative number of these cells varies with individuals.

5. Amoeboid compartment cells (figs. 5 and 6). These cells appear to be hyaline amoebocytes upon superficial examination of the unstained living cell, but careful examination of them under favorable conditions unstained or stained with some of the vital dyes reveals strands of cytoplasm dividing the cell into vacuoles which may be angular or globular. Most of these cells do not show visible granules or rods in the vacuoles; but some do. In most of them the entire vacuolar contents take the vital stains. On the basis of their reaction to Janus green B and to osmic acid they may be divided into two varieties:

(a) Cells in which the vacuolar fluid stains pink with Janus green B. At times in the vacuolar fluid there are to be seen small dancing blue granules, which may be observed to agglutinate to form rods and masses. After osmic acid the vacuoles of these cells show fatty granules in the fluid and a peripheral fatty film.

(b) Cells in which the vacuoles stain pale blue with Janus green B. Osmic acid does not blacken these cells.

6. Vesicular signet-ring type of cell (fig. 7). These are much like the cells of type 5 except that there is a single large vacuole surrounded by a thin layer of protoplasm, which is thicker in the region where the nucleus is located. Some of them show stainable granules in the vacuole fluid; some do not. On the basis of their reaction to osmic acid and Janus green B there are two varieties of these cells comparable to varieties 5a and 5b above.

7. Finely granular amoebocytes (figs. 8, 9 and 10). This is a lymphocyte-like cell. There is a large nucleus surrounded by a thin layer of cytoplasm. The larger cells have a thickened layer of cytoplasm. Rods and granules, presumably mitochondria, in the cytoplasm of these

cells stain a deep blue with Janus green B. I look upon this as the primitive type of cell in ascidian blood from which the other cell types are derived. A series of stages linking it up with the coarsely granular amoebocytes may be picked out, or on the other hand, transition stages may be found connecting it with the amoeboid compartment cells. I think it probable that the compartment cells through the formation of a fatty film in the vacuoles and the acquisition of pigment in this fat may become green cells.

These cells were found to be phagocytic to trypan blue after hypodermic injections on two successive days. A few signet-ring cells and cells with several vacuoles (transition stages) showed trypan blue in the cytoplasm but not in vacuoles.

The test of this species contains large signet-ring cells (or "bladder cells") three to four times the diameter of corresponding cells of the blood, variations of it with several vacuoles and also small cells with fine granulations. Some of these small cells have vacuoles; some have none. They probably give rise to the bladder cells of the test. Gradations from the small granular to the large bladder cells may be picked out.

STYELA PLICATA

1. Amoeboid cells with colorless globules (fig. 11) that take a slate color with osmic acid and stain a little with Sharlach R. There is a region without globules in which the nucleus may be demonstrated. I consider that these cells are homologous to the green cells of other species. Some of the larger vacuoles show that the fatty portion of the globules forms a sort of shell or film around a central non-fatty center. The fatty film of the globules stains with Nile blue sulphate, neutral red, methylene blue and other basic vital stains. Neutral red gives a deep red color to the globules indicating that they are acid in reaction. They stain a light blue with Janus green B, later becoming a deep blue.

2. Orange cells are present but are not frequent in blood drawn from the heart or blood vessels. They are similar to orange cells in *Perophora viridis* and *Phallusia hygomiana* though paler in color. The globular orange masses are quite resistant to reagents. Cells that are filled with orange colored masses and which are probably identical to blood cells, are present in considerable numbers in the mantle around the inhalent and exhalent siphons.

I have not found any cells in the blood of *S. plicata* comparable to the colorless morula cells present in some other species.

3. Coarsely granular amoeboid cells (figs. 12 and 13), about like the

corresponding cells found in all other species previously studied by me are present in *Styela*. Coarse granules that do not blacken with osmic acid crowd the endoplasm. Some cells may have other cells and what appear to be cell fragments, presumably ingested, present in the cell body (fig. 13).

4. Amoeboid compartment cells, similar to those described for other species, are seldom found (or are with difficulty recognizable). When found the compartments or vacuoles are more numerous and smaller and more globular than is the case in most other species and they contain only one or a few granules to a vacuole. There is a type of cell present in considerable abundance that I consider to be the probable equivalent in *Styela* of the compartment amoeboid cell:

5. Granular amoeboid cells (figs. 14 and 15) with a more or less centrally located nucleus surrounded by many small granules and a peripheral layer of hyaloplasm. The granules are fairly uniform in size and somewhat less than one micron in diameter. They take neutral red, Nile blue sulphate and the other vital stains used less readily than do the larger globular bodies in the "green cell" type. They do not blacken with osmic acid. The cells may spread out into thin films, at which times, with high power and bright light, the granules may be seen to show brownian movement. The granules are located apparently in minute vacuoles. I look upon this cell as being the homolog of the amoeboid compartment cell of other species. Now and then a cell with large vacuoles is found. When undergoing amoeboid motion the cells usually have lobose pseudopodia, though filamentous ones may be formed involving first the hyaloplasm and later the granular endoplasm. There is some evidence to indicate that cells of this type give rise to "green cells." After Nile blue sulphate or Janus green staining I have observed cells of this type with a few large deep staining masses apparently like those of "green cells"—possibly formed from the fusion of the finer granulations and the vacuoles that enclose them.

6. Signet-ring cells (figs. 18 and 19) are quite rare. One may examine several cover glass preparations of blood without finding one. Their structure is the same as that described for other forms in which they are more abundant. They might be derived from the granular cells of type 5 by a migration of the nucleus to the periphery and a liquefaction of the endoplasm.

7. Finely granular amoeboid cells of the lymphocyte type (figs. 16 and 17) are fairly numerous. The cells are small but vary in size. The layer of cytoplasm around the nucleus varies in thickness. Gradations from small cells with few granules that stain with the vital dyes

up to cells with many small granules (cells of type 5) may be found. In animals injected with trypan blue for three successive days these cells only showed the stain.

The characteristic cells of the test are granular amoeboid cells. The granules are fairly coarse and many of them stain with neutral red. No vesicular cells like those abundant in the test of *Phallusia hygomiana* were found in the test of *Styela plicata*.

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EXPLANATION OF FIGURES ON PLATE 29

All figures are camera lucida drawings made at a magnification of approximately 2400 diameters.

Figs. 1 and 2. Colorless morula cells from blood of *Phallusia hygomiana*. Figure 1 shows the nucleus drawn after fixation of the cell.

Fig. 3. Coarsely granular amoeboid cell from the blood of *Phallusia hygomiana*.

Fig. 4. Finely granular cell of the lymphocyte type, which has acquired some coarser granules, from the blood of *Phallusia hygomiana*. It is possibly a transition stage in the development of the type of cell shown in figure 3.

Figs. 5 and 6. Amoeboid compartment cells from the blood of *Phallusia hygomiana*. Figure 5 represents what is probably a transition stage in the development of cells of the cell type shown in figure 7.

Fig. 7. Vesicular signet-ring cell from the blood of *Phallusia hygomiana*.

Figs. 8, 9 and 10. Finely granular amoeboid cells (lymphocyte type) from the blood of *Phallusia hygomiana*. Figure 8 shows a cell of this type with vacuoles. It is probably a stage in the development of the type of cell shown in figure 6.

Fig. 11. Amoeboid cell with colorless globules from the blood of *Styela plicata*. This is probably the homolog of the green cell of other species.

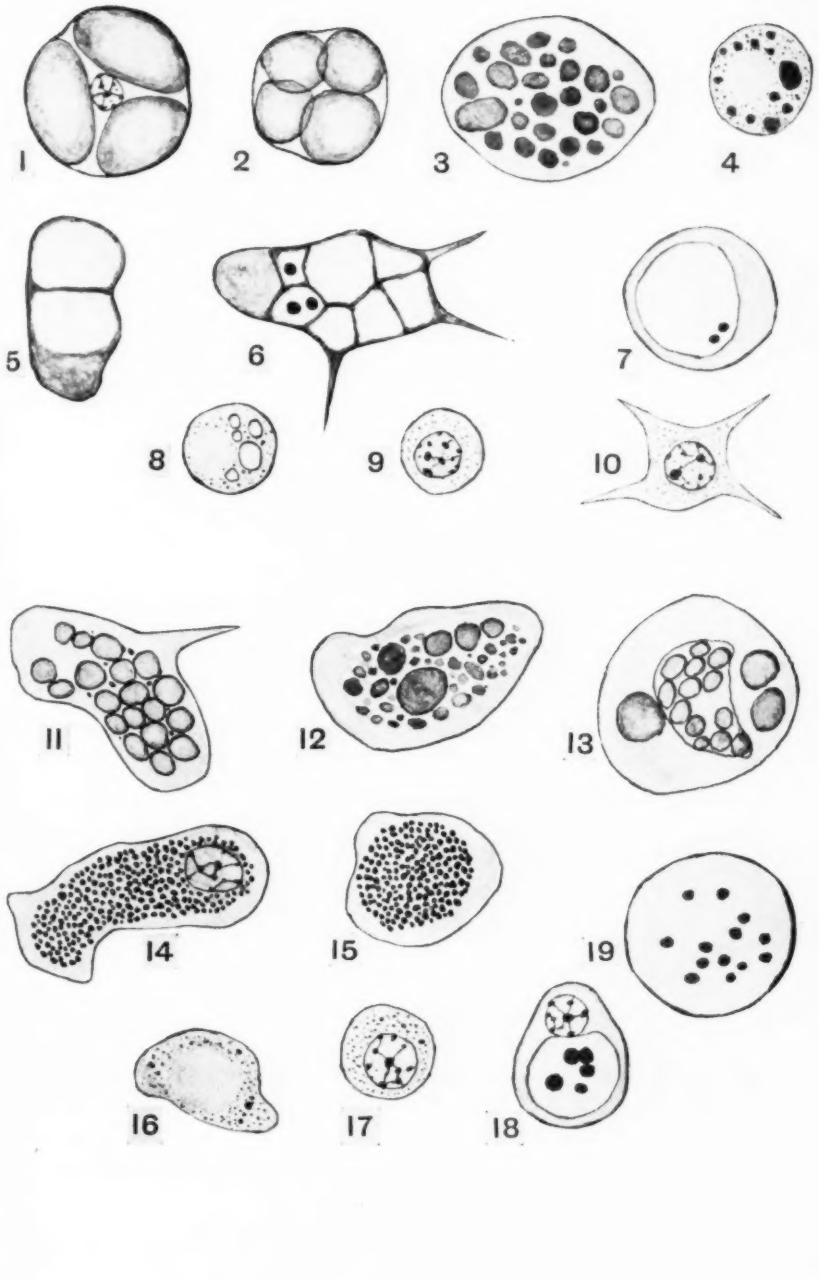
Figs. 12 and 13. Coarsely granular amoeboid cells from the blood of *Styela plicata*. Figure 13 shows an ingested cell of the type shown in figure 11.

Figs. 14 and 15. Granular amoeboid cells from the blood of *Styela plicata*. This type of cell is probably homologous to the compartment cells of other species.

Figs. 16 and 17. Finely granular amoeboid cells (lymphocyte type) from the blood of *Styela plicata*.

Figs. 18 and 19. Vesicular signet-ring type of cell from the blood of *Styela plicata*.

PLATE 29



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FLORA OF THE TRYON REGION

Part V. Wintergreen Family to Lobelia Family (Pyrolaceae to Lobeliaceae)

By Donald Culross Peattie

Family 91. PYROLACEAE (Wintergreen Family)

708. **Clethra acuminata** Michx. (Sweet Pepperbush. White-alder)

This endemic of the Southern Appalachians is very common in our region, especially in the mountains, but it is not unknown in piedmont glens. Specimens: Columbus, 1897 (Towns.). Vaughan's Creek, below Godshaw Hill, Aug. 11, 1921; on dripping rocks, Hogback Mt., Aug. 14 and Sept. 6, 1921 (PT. nos. 1165–1167, 1259, 1473, 1474; the last two specimens in fruit.) Begins to bloom in July.

709. **Chimaphila maculata** (L.) Pursh. (Spotted Wintergreen, Ratsvein)
Pyrola maculata L.

Very common in poor, acid soil, chiefly under pines. Specimen: Columbus, June 16, 1899 (Towns.). Blooms into July.

It has been reported to me that Mr. Isaac Rockwell Fiske, an amateur naturalist well-known in this region at one time, found on Whiteoak a species of *Pyrola*, possibly *Pyrola americana*. This is indeed a highly creditable report, but lacks good substantiation.

Family 92. MONOTROPACEAE (Indian Pipe Family)

710. **Monotropa uniflora** L. (Indian Pipes. Corpse Plant)

This well-known saprophyte with a fungoid odor is locally frequent, especially in Porter loams, but is occasional on the Cecil clays. It begins to bloom in June. Specimens: Summit of Whiteoak Mt., July 21, 1921 (PT. no. 1042). Hogback Mt., Sept., 17, 1927 (Wherry).

711. **Hypopitys americana** (DC.) Small (Pinesap. False Beech-drops)
Monotropa Hypopitys Michx., not L.
Hypopitys lanuginosa Nutt.
Hypopitys Hypopitys Small

This curious little plant, of rich woods, blooming from May to October seems to have been collected only once in our area. Specimen: South of Columbus, May 24, 1899 (Towns.).

712. **Monotropsis odorata** Ell. (Sweet Pinesap)
Schweinitzia odorata Ell.

This delicate little plant, with the odor of violets, is frequently so hidden beneath leaves that it is entirely overlooked. It is the earliest of our members of the family to bloom, and while no specimens here enumerated show it, I think, from having found recently faded flowers in the latter part of March that it may be accounted for as one of our earliest (and least often-noticed) spring-flowering herbs. Specimens: In pine woods, Columbus, 1897 (Towns.) Tryon, March 30, 1919 (Day). Piney Mt., under *Pinus virginiana*, April 20, 1922 (PT. no. 1659).

Family 93. ERICACEAE (Heath Family)

713. **Rhododendron arborescens** (Pursh) Torr. (Smooth Azalea)
Azalea arborescens Pursh

This and the three following species, members of the section Azalea are called by country people "honeysuckle." This Southern Appalachian endemic is not frequent; it generally occurs along streams in sunny thickets in the mountains and foothill glens. Specimens: Spring Park, June 7, 1897 (Towns.). Saluda, May 1899 (Church). Along Vaughan's Creek, June 29, 1921 and, in fruit, same habitat, Aug. 11, 1921 (PT. nos. 732–734, 1157, 1158). This is the last of the Azaleas to bloom.

714. **Rhododendron nudiflorum** (L.) Torr. (Common Azalea)
Azalea nudiflora L.
Azalea periclymenoides Michx.

This is the first of the azaleas to bloom and is common throughout in both Porter and Cecil soils. It is highly variable in its colors and

corolla markings; though most abundant in April it is not unknown into June. Specimens: Tryon, April 8, 1897 (Towns.). Tryon, April 9, 1911 (Day).

715. **Rhododendron canescens** (Michx.) G. Don. (Clammy Azalea)
Azalea canescens Michx.
Azalea prionophylla Small

In woods, occasional, with the preceding, and quite possibly not distinct from the variable common azalea. Specimens: Tryon, May 1918 (Millsp. no. 4071). By mountain streams, Rocky Spur, 2000 ft. alt., Sept. 6, 1921 (PT. nos. 1477, 1478, in fruit).

716. **Rhodendron calendulaceum** (Michx.) Torr. (Flame Azalea)
Azalea calendulacea Michx.
Azalea lutea L., not *Rhododendron luteum* Sweet.

This plant, though not deliciously fragrant like the common azalea is perhaps our most magnificent flower as respects colors. Possibly because of garden soil conditions, or because its orange, red and yellow colors mix badly with most garden flowers, this species usually appears dingy and tawdry in cultivation, and many gardeners are disappointed in it. But in its native Appalachian habitat it is incomparable. In blooming period this is intermediate between *R. nudiflorum* and *R. arborescens.* Specimens: Little Warrior Mt., May 7, 1897 (Towns.). Tryon, May 1899 (Church.). Tryon, May 12, 1911 (Day).

717. **Rhododendron maximum** L. (Late Rhododendron. Great Laurel)

Everyone who has ever seen the Blue Ridge knows this tree or big shrub, with its fine foliage, and its white or rose flowers. In our area it is very common in all dark cool mountain coves, and occurs in the foothills in rich shaded glens. Specimens: Side of Tryon Range, June 27, 1897 (Towns.). Pearson's Falls, June 27, 1921 (PT. no. 683). Blooms from middle of June and for a month thereafter. Country people call this, not *Kalmia*, "laurel."

718. **Rhododendron catawbiense** Michx. (Catawba Rhododendron. Mountain Rose Bay)

When, in May and early June the summits of the Black Mt. range are ablaze with this species, with its gorgeous purple flowers, they are

an incredible sight. In a rare and scattering way it descends from the sub-alpine zone into the lower mountains, or even the piedmont. In our area it occurs only on the high ridges of Rocky Spur, where it was discovered by Mr Edward Holmes, of Tryon, brother of the State Forester of North Carolina. Mr. Holmes successfully transferred some plants to the Leitner's garden, and from those bushes was collected a specimen in full flower on May 27, 1927, by Dr. Edgar Wherry.

719. **Rhododendron minus** Michx. (Early Rhododendron)
Rhododendron punctatum Andrews

This resembles *R. maximum*, but is a much smaller bush, with smal er leaves, and smaller pink flowers appearing six weeks to two months sooner. It is common in the lower mountains and foothills, both with *R. maximum* n r ch glens, and also in somewhat dr.er and sunnier spots. Specimen: Three m les north of Millspring, May 27, 1927 (Wherry). April, May.

Var. **margarettae** (Ashe) Peattie. *comb. nov*
Rhododendron carolinianum var *margarettae* Ashe. Rhodora vol. 23, pp. 177–179 (1921).

Although Mr. Ashe described his variety, type specimens of which come from our area, as a variety of *R. carolinianum* Rehder, and some authorities have even regarded it as a synonym of *R. carolinianum* var. *album* (Ke sey) Rehder, it is perfectly evident not only from the specimens, but even from Mr. Ashe's original description that his variety belongs with *R. minus* in many essentials, i.e., the lobes of the corolla lepidote outside; the filaments exserted; the leaves pointed at each end and gray lepidote beneath. In these respects it is certainly close to *R. minus*, and far from *R. carolinianum*. The flowers are white in this variety. Some of the specimens cited by Ashe do, however, belong to the white-flowered variety of *R. carolinianum*. The following specimens from our area may be cited: Skuyuka Creek, May 3, 1897 (Towns.). Tryon, April 9, 1911 (Day). Tryon, April 20, 1923 (PT. no. 1864). Ashe cites Biltmore Herbarium specimen no. 4463 from Tryon, but this appears to me to be distinctly *R. carolinianum* var. *album*, and so evidently Rehder considered it.

720. **Rhododendron carolinianum** Rehder (Early Rhododendron)
Rhododendron punctatum of reports, but not Andrews

This species, the compact, purple-flowered bush of higher altitudes may not exist in our area in typical form. My specimens, nos. 1033, 1034, from "The Narrows" Whiteoak Mt., 3000 ft. elevation, July 21, 1921, are in fruit and hence it is not possible to tell whether they are white-flowered or purple. Probably most of our species belong to:

Var. **album** (Kelsey) Rehder
Rhododendron punctatum var. *album* Kelsey

This form is rarer with us than *Rhododendron minus* and its white variety, with which latter it is often confused. It is found in high cool mountain glens, associated with the hemlocks. Specimens: Tryon, April 20, 1897 (Bilt. Herb. 4463). Rich woods, Melrose, April 20, 1922, and Pearson's Falls, May 17, 1926 (PT. nos. 1666, 2185). The blooming of this plant is generally several weeks earlier than of *R. minus*.

Although this study is a catalogue and not a descriptive flora, I venture below to give a provisional key to the evergreen rhododendrons because they occur widely in Western North Carolina, and give much difficulty in identification, at least as respects the recent segregates of "R. punctatum." Descriptions of them have not appeared in recent manuals except in Bailey's "Manual of Cultivated Plants," and the proper placing of the white-flowered forms has, in my view, never before been pointed out.

KEY TO **Rhododendron**, SECTION *Eurhododendron* IN NORTH CAROLINA

Leaves lepidote beneath; ovary also lepidote
- Under side of leaves rusty-lepidote; corolla tube shorter or as long as the lobes, not or only slightly spotted, gradually widened; leaves cuneate at base
  - Flowers purple ..... *R. carolinianum*
  - Flowers white ..... *R. carolinianum* var. *album*
- Under side of leaves glandular-lepidote; corolla tube longer than its lobes; leaves acute at both ends; upper corolla lobe spotted with greenish; lobes lepidote outside
  - Flowers roseate ..... *R. minus*
  - Flowers white ..... *R. minus* var. *margarettae*

Leaves glabrous, ovary rusty-tomentose
- Both ends of the leaf acute, blades lanceolate-oblong; flowers rose-colored, spotted within with greenish, or wholly white but for the spottings *R. maximum*
- Leaves broader, blunter; flowers purple ..... *R. catawbiense*

721. **Kalmia latifolia** L. (Mountain Laurel. Calico Bush)

This is certainly our commonest ericaceous shrub; possibly the commonest of all our shrubs, occuring abundantly both in the mountains (where often a small tree) and on the piedmont. Apparently our most acid soils are often found under it, and the plants that will tolerate association with it on such soils are few. A common ecological association, very characteristic of the more acid soil and poor in species, is the following three-tiered arrangement: overhead, *Pinus echinata*; middle stratum, *Kalmia latifolia;* on the ground, *Chimaphila maculata.* Mountain people call this "ivy" and "ivory." Specimens: Tryon, May 30, 1918 (Millsp. no. 4073). Tryon, May 17, 1911 (Day). Tryon, May 2, 1919 (PT. no. 0174).

722. **Epigaea repens** L. (Trailing Arbutus. Mayflower)

This is common in the poorer types of soils, and under the thinner types of forest cover. Now becoming infrequent near the town, but still very fine on mountain tops, remote woods, etc. Specimens: Beside a road, April 3, 1897. (Towns.). Tryon, March 9, 1911 (Day). Tryon, May 1918 (Millsp. no. 4037).

723. **Oxydendrum arboreum** (L.) DC. (Sourwood. Sorrel-tree)
Andromeda arborea L.

This characteristic Alleghenian forest type is the only tall tree of its family in our area. It is very conspicuous in autumn for its gorgeous coloration, and in early summer the noise of bees in its innumerable high-waving racemes of flowers is a very characteristic forest sound. It is an abundant tree on dry hills of the foothill region, and on the warm slopes of the mountains, attaining at times fine dimensions. Pinchot and Ashe ("Timber Trees of North Carolina") say "it reaches its largest size on the eastern slopes of the Blue Ridge)"—where our area lies. Specimens: Tryon, July 9, 1897 (Towns.). Tryon, June 20, June 29, 1921; Whiteoak Mt., July 21, 1921; in fruit, Columbus, Oct. 1926 (PT. nos. 790, 791, 771, 1004, 2399).

724. **Leucothoe Catesbaei** (Walt.) D. Don (Fetter Bush)
Andromeda Catesbaei Walt.
Andromeda spinulosa Pursh

This handsome evergreen shrub is characteristic of the *Rhododendron maximum* thickets in the mountain glens and also in the foothills. It

is an Appalachian endemic that begins to bloom in March, is abundant in flower in April, and may continue to the first of June. Specimens: Tryon, April 28, 1897 (Towns.). Along Vaughan's Creek, May 1899 (Church.). Tryon, April 23, 1911 (Day). Vaughan's Creek, in fruit, June 29, 1921, and in flower April 20, 1923 (PT. nos. 739, 738, 760, 1874). Conspicuous in Glen Walden.

725. **Eubotrys recurva** (Buckley) Britton
Leucothoe recurva Gray
Andromeda recurva Buckley

Another Appalachian endemic, but perferring dry mountain and foothill slopes. Specimens: Tryon, April 12, 1897 (Towns.). Melrose Mt., April 18, 1919 (Day).

726. **Eubotrys racemosa** (L.) Nutt.
Andromeda racemosa L.

Occasional in upland woods. Specimen: Melrose Mt., April 10, 1922 (PT. no. 1637).

727. **Lyonia ligustrina** (L.) DC. (Male-berry)
Lyonia paniculata Nutt.
Vaccinium ligustrinum L.
Andromeda ligustrina Muhl.
Xolisma ligustrina Britton

A common shrub of moist or dry woods. Specimens: Tryon, June 3, 1897 (Towns.). Riverbanks, Tryon, Aug. 23, 1921 (PT. no. 1359).

Var. **foliosiflora** (Michx.) Fernald
Xolisma foliosiflora Small

Specimen: Tryon, May 14, 1911 (Day). Probably this variety is more common than the one specimen cited would indicate; the earlier blooming date of the variety is interesting.

728. **Lyonia mariana** (L.)D. Don (Stagger-bush)
Neopieris mariana Britton
Andromeda mariana L.
Pieris mariana Benth. & Hook.

Frequent shrub of dry or wet woods. Specimens: In dry woods, Tryon, Aug. 9, 1921; in moist woods along Vaughan's Creek, Aug. 11, 1921 (PT. nos. 1134, 1156).

729. **Gaylussacia baccata** (Wang.) C. Koch (Black Huckleberry)

In rocky woods. So far as collections up to date are concerned this must be rare, but it is possible that it will prove commoner with investigation. Specimen: Tryon, April 20, 1911 (Day).

730. **Gaylussacia dumosa** (Andr.) T. & G. (Dwarf Huckleberry)
Decamerium dumosum Nutt.

This is common on dry hillsides, under pine and hickory, on the micaceous schists. "Sandy swamps . . . . mostly on the coastal plain" (Gray's Manual) seems, so far as our area is concerned, to be an incorrect range and habitat. Specimens: Side of Tryon Mt., May 11, 1897 (Towns.). Tryon, May 1899 (Church.). Tryon, April 20, 1911, and May 14, 1919 (Day).

731. **Vaccinium arboreum** Marsh. (Sparkleberry)
Batodendron arboreum Nutt.
Batodendron andrachneforme Small

A common shrub or sometimes a small tree, in our area evergreen. The flowers are, unlike most other members of the genus, conspicuous; the fruit, from its habit of remaining green so long is called by many mountain folk "gooseberry." It frequents dry hillsides. Specimens: Side of Tryon Range, May 11, 1897; Spring Mt. Park, June 8, 1899 (Towns.).

732. **Vaccinium stamineum** L. (Deerberry)
Polycodium stamineum Greene
Picrococcus stamineus Nutt.

Frequent in dry woods. Specimen: Mountain glens, Melrose Mt., April 20, 1922 (PT. no. 638).

The Southern Gooseberry, *V. melanocarpum* Mohr (*Polycodium melanocarpum* Small) was reported by Woolson, but there are no specimens in support of this. However, it is highly likely that it does occur in our area, and will be found when this difficult genus has been more conscientiously collected in our region.

733. **Vaccinium neglectum** (Small) Fernald (Squaw Huckleberry)
Polycodium neglectum Small

This southern species is common on dry hillsides under shade. Specimens: Tryon, May, 1918 (Millsp. no. 4072). Tryon, May 8, 1919 (Day). Pacolet Heights, April 25, 1919 (PT. no. 0144).

734. **Vaccinium vacillans** Kalm (Late Low Blueberry)

In dry woods, and sandy or micaceous soil, quite common. Specimens: Side of Tryon Range, April 21, 1897 (Towns.). Tryon, April 17, 1919 (Day). Tryon, April 18, 1923 (PT. no. 1859).

735. **Vaccinium atrococcum** (Gray) Heller (Black High Blueberry)

Rare, in marshy ground. Specimen: In a swamp on the state line hill beyond the trestle, April 20, 1923 (PT. no. 1867).

736. **Vaccinium corymbosum** L. (Swamp Blueberry)

In low woods, or sometimes even upland pastures. Specimens: Columbus, April 20, 1899 (Towns.). Tryon, May 12, 1919 (PT. no. 0215).

737. **Vaccinium virgatum** Ait. var. **tenellum** (Ait.) Gray (Blueberry)

Occasional in dry soil under pines. Specimen: Above the Golf Links, April 28, 1919 (PT. no. 0159).

Family 94. DIAPENSIACEAE (Diapensia Family)

738. **Galax aphylla** L. (Galax)

Mountain people sometimes call this skunk-flower, because in its neighborhood at flowering time is often a skunk-like or alliaceous odor, though the blossoms themselves when brought to the nose have no such odor. Nothing is more characteristic of the floor of dark pine woods where laurel or rhododendron are the secondary stratum of vegetation, than the beautiful leaves of this little plant, which belongs to one of the rarest and most interesting of all plant families. There are in it not above ten species in all, one circum-polar and alpine, the others found mostly in the mountains of Asia and the eastern United States. Specimens: Fox Mt., May 18, 1897 (Towns.). Tryon, May 12, 1911 (Day).

Tryon, May 15, 1918 (Millsp. no. 4032). In fruit, Tryon, June 20, June 29, 1921 (PT. nos. 630, 757).

Shortia galacifolia Gray may now almost be considered an established plant in our area. This beautiful little species, native in the Highlands country and the Oconee region, is historically famous. I have related its romantic history in full detail in *Farm and Garden* for June, 1922. In May 1919 I collected a quantity of this plant from its original station and transplanted it to Pearson's Falls. Since then it has spread in this favorable habitat, and others have transplanted from my original colony; there is now a colony established in the wild at Glen Walden, whither it was removed by Mr. C. C. Crandall in 1925. As it will undoubtedly thrive in our region, this note may serve as a guide to future botanists that it was not originally native here, though naturalized in the appearance of a native.

Family 95. PRIMULACEAE (Primrose Family)

739. **Lysimachia quadrifolia** L. (Loosestrife)
Lysimachia punctata Walt.
Lysimachia hirsuta Michx.

In sterile piedmont woods, abundant. There seem to be two distinct extremes in our area: (1) a pale green hairy plant, with leaves mostly in whorls of two or three, the blades thin and narrowly lanceolate-ovate, the whorls few in number; no rank odor present. (2) A dark green smooth plant with numerous whorls of four or five or six leaves each, the blades thick and broader; a strong rank odor pervades the plant which is in every way more robust and vegetative. The differences may be due to environment purely. Specimens: Tryon, May 22, 1897 (Towns.). Tryon, May 17, 1918 (Millsp. no. 4123). Tryon, June 24, 1923 (specimen sent me by Mr. Edgar Upton).

Lysimachia Nummularia L. (Moneywort) is a European species planted frequently on old garden walls and tending to escape into neighboring grounds. It is uncertain as yet if it is a permanently naturalized plant.

740. **Steironema tonsum** (Wood) Bicknell
Steironema intermedia Kearney

This is frequent in rich foothill or mountain woods, or along brooks. Specimens: Side of Tryon Mt., June 21, 1899 (Towns.). Rich woods, Whiteoak Mt., July 21, 1921 (PT. no. 1009).

741. **Anagallis arvensis** L. (Pimpernel. Poor-man's-weather-glass)

A little weed, or old-fashioned garden flower, of which the blossoms close quickly in cloudy weather, introduced from Europe and, rarely,

established in our area. Specimen: Roadside between Landrum and Sandy Plains, in fruit, June 16, 1897 (Towns.).

742. **Dodecatheon Meadia** L. (Shooting Star)
Meadia Dodecatheon Mill.

This beautiful plant is common on the prairies of the Middle Western States; its presence in our area is distinctly anomalous, and indeed it has never been collected but once; it was found thirty-two years ago by the leading discoverer of rare finds in our area. Specimen: White Oak Mt., May 19, 1897 (Towns.).

Family 96. DIOSPYRACEAE (Ebony Family)

743. **Diospyros virginianus** L. (Persimmon)

This well-known tree is abundant in our area, both in open fields as single specimens, and on the hills in nearly pure stands. While it may be true that a frost is not what ripens the persimmon, as is generally supposed, the fact comes nearly to the same thing. Persimmons are not edible until very late in the year, about the time when the first frosts appear in this mild climate. In fact there are just a few days in the life of a persimmon when it is edible, in that time between the moment when it drops off the tree and the time when it begins to spoil. The persimmon, like the papaw, is still in the stage of a completely wild fruit, that is, good strains exist, along with bitter strains, but little has been done to separate and propagate from desirable individuals. Specimens: Columbus, May 27, 1897 (Towns.). Tryon, May 23, 1926; young fruit, Pearson's Falls, June 29, 1921; mature fruit Oct. 23, 1926 (PT. nos. 2238, 687, 2390).

Family 97. STYRACACEAE (Storax Family)

744. **Styrax grandifolia** Ait. (Storax)

This is a fine big shrub, handsome in all its parts, which reaches rather a western limit in North Carolina in our area. It has been so far collected only in a marshy wood southeast of Columbus, where a number of other plants predominantly of the eastern part of the county, such as *Magnolia virginiana*, are confined, so far as regards this county. Specimen: "The Shoals," May, 1918 (Millsp. no. 4101).

745. **Halesia carolina** L. (Silver-bell Tree)
Halesia tetraptera L.
Mohrodendron carolinum Britton

This beautiful little tree is common in our area throughout, from low woods all the way to the summit of Hogback Mt. Specimens: Along Horse Creek, south of Columbus, in fruit, Aug. 14, 1897 (Towns.). Along the Pacolet River, May, 1899 (Church.). Near Millspring, April 15, 1923; in fruit, on Ballenger's Hill, June 20, 1921 (PT. nos. 1842, 606, 608).

Var. **monticola** Rehder

A larger-flowered and finer variety. Specimen: Tryon, April 18, 1911 (Day).

Family 98. SYMPLOCACEAE (Horse-Sugar Family)

746. **Symplocos tinctoria** (L.) L'Her. (Horse-sugar. Sweet Leaf)
Hopea tinctoria L.

Of this curious tropical family we have but this one representative, with sweet-tasting leaves. Despite Coker and Totten's statement ("Trees of North Carolina") that it is found in the lower mountains but not commonly, it seems to be common with us, almost always as a shrub rather than a tree. Specimens: Round Mt., April 14, 1897 (Towns.). Lynn, May, 1899 (Church.). Tryon, April 25, 1911 (Day). In fruit, Vaughan's Creek, Aug. 9, 1921; on Tryon Mt., April 26, 1923, in flower (PT. nos. 118–120, 1621).

Family 99. OLEACEAE (Olive Family)

747. **Ligustrum vulgare** L. (Privet)

Introduced from the Old World and naturalized, in moist woods near dwellings. Specimen: Spring Mt. Park, June 7, 1897 (Towns.).

748. **Syringa vulgaris** L. (Lilac)

Introduced from the Old World and naturalized, in moist woods near dwellings. I have noted several specimens that have naturalized themselves in "Valhalla."

749. **Chionanthus virginica** L. (Fringe-bush. Old Man's Beard)

This splendid flowering bush or tree is more often seen in cultivation than in the wild, but it is native with us, as well as much favored in our local gardens, and chooses dark moist glens near streams. Specimens: Side of Tryon Mt., May 5, 1897 (Towns.). Tryon, May 7, 1911 (Day). Along Vaughan's Creek, May 11, 1926 and, in fruit, same habitat, June 29, 1921 (PT. nos. 2174, 730, 731, 737).

"January Jasmine" (*Jasminum nudiflorum*) and golden-bells (*Forsythia suspensa, F. Fortunei, F. intermedia* var. *spectabilis*) are very common in gardens in our area.

750. **Fraxinus americana** L. (White Ash)
Fraxinus alba Marsh.
Fraxinus epiptera Michx.

This splendid tree, of great commercial importance, is possibly somewhat more abundant than the following citations would indicate, but is probably less common than the following species. Specimens: Spring Mt. Park, in fruit, June 8, 1899 (Towns.). Saluda (Greene). Flowers in April; chiefly in forests, on the loams.

751. **Fraxinus biltmoreana** Beadle (Biltmore Ash)

Probably the lumberman makes no distinction between this and the preceding; the differences are not beyond suspicion of being pedantic, or at least worthy only of varietal rank. It has however become customary in botanical circles to separate the tree with pubescent branches and more slender fruit. Common with us especially at the base of the mountains, near brooks and in wet meadows, often singly. Specimens: In open ground, Congaree fine sandy loam, "Valhalla," in fruit, Aug. 25, 1921; moist meadow, Tryon, Aug. 29, 1921; rich woods, "Valhalla" April 20, 1922; cool glen, Tryon, May 23, 1926 (PT. nos. 1383, 1418, 1639, 2252). All specimens in fruit; the flowers appear as early as March.

Family 100. LOGANIACEAE (Logania Family)

752. **Polypremum procumbens** L.

This inconspicuous weedy annual is somewhat infrequent in sandy fields and abandoned cultivation. Specimens: Tryon, July 22, 1897 (Towns.). Pastures, Tryon, July 18, 1921 (PT. no. 996).

The above is the only known representative of this interesting tropical family in our area, but two other species closely approach our southern borders. *Gelsemium sempervirens*, the yellow jessamine grows near Spartanburg, and *Spigelia marilandica* the Indian Pink, a striking plant the medicinal properties of which were first discovered by Dr. Alexander Garden of Charleston (see Introduction page 97) occurs in Greenville County. Much cultivated are species of *Buddleia*—in our area chiefly *B. japonica, B. superba, B. Foresttii*.

Family 101. GENTIANACEAE (Gentian Family)

753. **Sabbatia angularis** (L.) Pursh (Rose-gentian)
Chironia angularis L.

Common in dry fields, along hedgerows, and in the wayside grasses. Specimens: Side of Tryon Mt., July 5, 1897. Tryon, Aug. 28, 1921 (PT. no. 1410).

754. **Gentiana decora** Pollard (Gentian)
Dasystephana decora Small

This pretty Appalachian endemic with purple flowers is one of the commonest in our area. Specimens: Spring Mt. Park, October, 1897 and, as to left hand specimen, in Townsend's private herbarium, on sheet marked "G. quinquefolia," Columbus, Oct., 1897 (Towns.). Kennedy's Farm, Tryon Mt., Dec. 28, 1920 (PT. no. 1582).

755. **Gentiana latifolia** Chapm. (Gentian)
Dasystephana latifolia Small
Gentiana Elliottii var. *latifolia* Chapm., not *G. linearis* var. *latifolia* Gray

Quite frequent in fields and woods; the leaves are by no means always broad, being sometimes almost linear-oblong; flowers rose-purple. Specimens: Spring Mt. Park, Oct., 1897; Tryon, Nov. 27, 1918 (Day). Low field, Vaughan's Creek, below Godshaw Hill, Nov. 10, 1926 (PT. no. 2379).

756. **Gentiana Saponaria** L. (Bottle Gentian)
Dasystephana Saponaria Small
Gentiana Catesbaei Walt.
Gentiana pneumonanthe Michx.
Pneumonanthe Saponaria F. W. Schmidt

Of this species there seems to be but one specimen from our area, though doubtless it is more common. Miss Day says "found them bleached white." They were not necessarily bleached; albino forms occur in several of the species. Specimen: Tryon, Oct., 1910 (Day).

757. **Gentiana villosa** L. (Green Gentian. Sampson's Snakeroot)
Gentiana Saponaria Michx., not L.
Gentiana ochroleuca Froel.
Dasystephana villosa Small

Frequent in mountain or foothill woods, on cliffs, etc. Specimens: Columbus (Oct.) 1899 (Towns.). Piney Mt., Nov. 24, 1918 (Day). Hogback Mt., Sept. 17, 1927 (Wherry).

758. **Gentiana puberula** Michx. (Gentian)
Pneumonanthe villosa Greene

Probably not infrequent, there is so far but one collection of this rose-purple gentian. Specimen: Hogback Mt., Sept. 17, 1928 (Wherry).

759. **Gentiana quinquefolia** L. (Gentian)
Gentianella quinquefolia L.
Gentiana quinqueflora Hill
Gentiana amarelloides Michx.
Aloitis quinqueflora Raf.

Mountain and foothill woods, not infrequent. Columbus, Oct., 1897 (as to right hand specimen on sheet. Towns.). Hogback Mt., Sept. 17, 1928 (Wherry).

The gentians of our area, while not numerous as compared with the gentians of the Rockies, the Alps, etc., are certainly of considerable interest for the eastern United States. The whole of the New England States have no more species than this one small county, according to Gray's "Manual." Knowledge of the species and distribution of gentians in the whole of western North Carolina is still incomplete, for the reason that few people study the autumn flora. Because most manuals make the identification of gentians unnecessarily difficult and some of the southern species are imperfectly known, a key to some of the common species is here appended in the hope that it may prove serviceable in advancing knowledge of this interesting genus.

KEY TO SOME COMMON NORTH CAROLINA GENTIANS

Corolla without plaits in the sinuses of the lobes; calyx without an interior membrane

Flowers large, solitary on long terminal peduncles, calyx 4-cleft, its lobes

ovate and lanceolate; corolla with a bell-shaped tube, 2.5–6 cm. long, deep blue or rarely white, the lobes deeply fringed and wedge-obovate. *G. crinita*
Flowers smaller, generally in clusters of 5, the peduncles very short; calyx 5 cleft, its lobes awl-shaped; corolla with a slender obconical tube, 1–2 cm. long, pale blue or greenish yellow, its lobes triangular-ovate, not fringed *G. quinquefolia*
Corolla with plaits in the sinuses of the lobes; calyx with an interior membrane
Calyx lobes smooth and glabrous, or essentially so; flowers greenish yellow *G. villosa*
Calyx lobes ciliate-scabrous; flowers blue, purple or rarely white or greenish
Corolla open-funnelform; anthers essentially separate from each other though often converging
Calyx lobes lanceolate; flowers clustered, or rarely solitary; seeds winged . . . . . *G. puberula*
Calyx lobes thread-like; flowers solitary and terminal; seeds wingless . . . . . *G. Porphyrio*
Corolla bell-shaped funnelform; anthers coherent into a ring or tube
Corolla lobes about as long as the plaits; stems glabrous. *G. Saponaria*
Corolla lobes longer than the plaits; stems pubescent
Calyx tube pubescent; flowers blue-purple . . . . . *G. decora*
Calyx tubes glabrous; corolla rose-purple . . . . . *G. latifolia*

760. **Obolaria virginica** L. (Pennywort)

A curious and rather pretty little flower of the Porter soils under shade, especially in cool mountain ravines. Specimens: Side of Tryon range, March 22, 1897 (Towns.). Tryon, March 24, 1919 (Day). Melrose, April 10, 1923 (PT. no. 1841). Tryon Mt., April 9, 1928 (Kimber).

Family 102. APOCYNACEAE (Oleander Family)

761. **Vinca minor** L. (Periwinkle)

Introduced from Europe, and escaping to woods and rocks and walls, especially from country graves. Specimen: Mountain woods, Howard's Gap, April 26, 1919 (PT. no. 0151).

762. **Amsonia Tabernaemontana** Walt. (Blue Milkweed)
Tabernaemontana Amsonia L.
Amsonia Amsonia Britton
Amsonia latifolia Michx.
Amsonia salicifolia Pursh

Frequent in moist woods, by springs, etc. and sometimes brought into cultivation here. A beautiful plant. Specimens: Side of Tryon

range, June 15, 1899 (Towns.). Tryon, April 9, 1911 (Day). Tryon, May, 1918 (Millsp. no. 4030). By springs, Melrose Mt., April 20, 1922 (PT. no. 1661).

763. **Apocynum androsaemifolium** L. (Spreading Dogbane)

In dry thickets, occasional, especially on the Tryon range. Specimen: Foot of White Oak Mt., June 8, 1899 (Towns.).

764. **Apocynum medium** Greene (Dogbane)

Occasional, same range as the preceding. Specimen: Side of Tryon range, June 19, 1899 (Towns.).

765. **Apocynum cannabinum** L. var. **pubescens** (R. Br.) DC. (Indian Hemp).
Apocynum nemorale Miller

Specimen: Summit of Skuyuka, May, 1899 (Church.). This seems to be the only collection of this fibre plant.

Family 103. ASCLEPIADACEAE (Milkweed Family)

766. **Vincetoxicum carolinense** (Jacq.) Britton (Angle-pod)
Gonolobus carolinensis R. Br.

Frequent on river banks and in thickets of the piedmont. Specimen: Banks of the lower Pacolet, June 2, 1919 (PT. no. 0255).

767. **Vincetoxicum obliquum** (Jacq.) Britton (Angle-pod)
Gonolobus obliquus R. Br.

Stream banks, and thickets, frequent on the piedmont. Specimen: "Huston Farm" near Columbus, June 2, 1897 (Towns.).

768. **Vincetoxicum hirsutum** (Michx.) Britton (Angle-pod)
Gonolobus hirsutus Michx.

Frequent, same habitat as the preceding. Specimen: Tryon, in fruit, Aug. 11, 1921 (PT. no. 1176).

769. **Acerates floridana** (Lam.) Hitchc. (Green Milkweed)
Acerates longifolia Ell.

Occasional in pine woods. Specimen: "Thousand Pines," in fruit, Sept. 6, 1921 (PT. no. 1460).

770. **Asclepias tuberosa** L. (Butterfly-weed. **Pleurisy-root**)

Common throughout, especially on the Cecil soils. Specimen: Spring Mt. Park, June 30, 1897 (Towns.).

771. **Asclepias amplexicaulis** Sm. (Milkweed)
Asclepias purpurascens Walt., not L.
Asclepias obtusifolia Michx.

In dry open soil, throughout. Specimen: Tryon, in fruit, July 22, 1897. Begins to flower in June.

772. **Asclepias phytolaccoides** Pursh (Milkweed)
Asclepias syriaca var. *exaltata* L.?

Common throughout in moist thickets. Specimens: Columbus, June, 1897 (Towns.). Tryon, June 2, 1919 (PT. no. 0258).

773. **Asclepias variegata** L. (Milkweed)

Common throughout in dry woods. Specimens: Tryon, May, 1899 (Church.). Spring Mt. Park, June 18, 1897 (Towns.). Tryon, May 28, 1919 (PT. no. 0241.)

774. **Asclepias quadrifolia** Jacq. (Milkweed)
Asclepias vanilla Raf

Frequent in mountain woods. Specimens: near Columbus, May 27, 1899 (Towns.) "Skuyuka," May, 1899 (Church.). Melrose, May, 1918 (Millsp. no. 4146).

775. **Asclepias verticillata** L. (Milkweed)

Very common in dry, sterile woods throughout. Specimen: Columbus, July 19, 1897 (Towns.). It is the last of the genus to bloom in this area.

Family 104. CONVOLVULACEAE (Morning-glory Family)

776. **Ipomoea Quamoclit** L. (Cypress Vine)
Quamoclit Quamoclit Britton

Quamoclit vulgaris Choisy
Quamoclit pennata Bozer

Showy little plant, naturalized from the American tropics. Frequent in fields and roadside thickets. (Noted.)

777. **Ipomoea coccinea** L.
Quamoclit coccinea Moench.

Naturalized from the American tropics, in fields and thickets. Specimen: Hedgerows, Tryon, Aug. 23, 1921 (PT. no. 1349). This has been present for at least thirty-three years. The preceding seems to be a more recent weed.

778. **Ipomoea hederacea** (L.) Jacq. (Small Morning-glory)
Convolvulus hederaceus L.
Pharbitis hederacea Choisy

Naturalized in fields from the American tropics. (Noted.)

779. **Ipomoea purpurea** (L.) Lam. (Common Morning-glory)
Convolvulus purpureus L.
Pharbitis purpurea Voigt.

Introduced from tropical America, cultivated and commonly escaped. (Noted.)

780. **Ipomoea pandurata** (L.) G. W. F. Mey. (Wild Sweet Potato. Old Man of the Earth)
Convolvulus panduratus L.
Convolvulus ciliolatus Michx.
Ipomoea ciliosa Pursh

Occasional in dry sandy and clay soil, trailing in the open, and climbing in thickets. The deep-buried tubers are edible, and often extremely large. Specimens: Tryon, June 23, 1897 (Towns.). Vaughan's Creek glen, in fruit, Aug. 12, 1921 (PT. no. 1198).

781. **Ipomoea lacunosa** L.

In moist thickets and along river banks, frequent. Specimens: Tryon, in fruit, Sept. 15, 1926 (Hunnew. no. 10,042). Tryon, Aug. 23, 1921 (PT. no. 1348).

782. **Ipomoea caroliniana** Pursh

Possibly native, possibly spreading from the southern coastal plain as a railway weed. Specimen: Railroad embankment, Tryon, June 29, 1921 (PT. no. 765).

783. **Convolvulus sepium** L. (Hedge Bindweed. Rutland Beauty)
Calystegia sepia R. Br.

This has been reported by Miss Wright in her list of Tryon plants and may, I think, be admitted as practically certain.

784. **Convolvulus spithamaeus** L.
Calystegia spithamaeus Pursh
Convolvulus stans Michx.

Miss Wright reports this from "Sunset Rock" Tryon Mt. It occurs in Henderson County and may reasonably be accepted as correct.

785. **Convolvulus repens** L.

A common, pretty, native field weed. Specimens: Saluda, May, 1899 (Church.). Railroad embankments, Tryon, June 20, 1921 (PT. no. 622). Two miles north of Millspring, May 27, 1927 (Wherry). Railroad embankment, Saluda, May 1918 (Millsp. no. 4147).

786. **Convolvulus arvensis** L. (Field Bindweed)

Common weed, naturalized from Europe. Specimen: Fallow fields, Tryon, May 23, 1926 (PT.).

Var. **obtusifolius** Choisy.

Warm slopes of cleared mountain land, Melrose, Sept. 3, 1921 (PT. no. 1456).

787. **Cuscuta arvensis** Beyrich (Dodder)

Common on various low plants. Specimens: Tryon, June 5, 1897 (Towns.). Godshaw Hill, Tryon, June 29, 1921 (PT. no. 772).

788. **Cuscuta Gronovii** Willd. (Dodder)

Common. In our region it attacks *Solidago, Aster, Convolvulus, Salix, Impatiens* and to a lesser extent *Acalypha, Rhus, Morus, Rubus,*

Pyrus, *Teucrium*, *Verbena*, *Boehmeria*. Specimen: On *Solidago*, Spring Mt. Park, Aug. 14, 1897 (Towns.).

789. **Cuscuta rostrata** Shuttlw. (Dodder)

This mountain species is locally abundant. In our area I have observed it chiefly on *Oxypolis* and *Aster divaricatus*. Specimens: On dripping rocks, Hogback Mt., in flower, Sept. 6, in fruit, Sept. 21, 1921 (PT. nos. 1481–1/2; 1256). *Fide* Dr. Yuncker. My specimens seem to me to differ in having larger flowers (5–8 mm. long), larger capsules (6 mm. long) their color very dark castaneous; the pedicels are shorter, and the stems more slender and dark orange. I shall not, however, differ with the specialist who did me the kindness to examine my specimens, as he has the advantage of seeing more intermediate forms than I.

Family 105. POLEMONIACEAE (Phlox Family)

790. **Phlox maculata** L. (Wild Sweet William)

Common in sunny mountain and foothill woods. Specimens: Side of Tryon range, June 19, 1897 (Towns.). Tryon, June 2, 1919 (PT. no. 0252).

791. **Phlox glaberrima** L.

Common in open woods and dry fields. Specimens: Side of Tryon range, June 10, 1897 (Towns.). Five miles north of Millspring, May 27, 1927; Hogback Mt., Sept. 17, 1928 (Wherry).

Var. **suffruticosa** (Vent.) Gray.

Mountain woods and open fields. Specimens: Tryon, June 20, 1921 (PT. no. 642; *fide* Wherry). Hogback Mt., Sept. 17, 1927 (Wherry).

792. **Phlox ovata** L.

Common in dry woods. Specimens: Side of Tryon range, June 19, 1897 (Towns.). Tryon, May 19, 1919 (Day). Washburn's Hill, June 2, 1919 (PT. no. 0253). Possibly some of these specimens are *Phlox carolina* L.

793. **Phlox amoena** Sims.

Common in dry woods and open fields. Specimens: Huston Farm, Columbus, May 8, 1897 (Towns.). Tryon, April 7, 1911 (Day). In dry soil, on the state line near the trestle, April 20, 1923 (PT. no. 1897).

794. **Phlox pilosa** L.

Frequent in dry woods and fields. Specimen: Tryon, May 23, 1926 (PT. no. 2258).

795. **Phlox stolonifera** Sims. forma **violacea** Peattie. *f. nov.*

The normal color of the corollas of *Phlox stolonifera* (*P. reptans* Michx.) is reddish-purple. In our area this color never occurs. The flowers are invariably a violet or lilac shade, similar to the color of *Vinca minor*. As this species enters into horticulture, where colors are important, and as our local form is markedly more desirable than the crude majenta shade of the typical species, I have ventured to give it the name: Forma *violacea*. *Corollae violaceae*. Specimens: Vaughan's Creek, April 14, 1919 (Day). Rich banks, along Vaughan's Creek, April 16, 1922, and Melrose, mountain woods, April 10, 1923 (PT. nos. 1603, 1801). Railroad track, Tryon, April 11, 1928 (Kimber). Dr. Wherry, finding the plants by my direction where I first noticed them in 1919 transplanted a colony to his garden. He also reports seeing this form in cultivation elsewhere in North Carolina, where brought in from the wild. It is, therefore, probably widespread in the North Carolina mountains. Also occurs in the South Carolina Blue Ridge.

796. **Phlox divaricata** L.

Phlox americana Sweet
Phlox glutinosa Buckley

This beautiful plant is represented by abundant specimens from Henderson, Greenville, and Spartanburg Counties. As it occurs in three out of four surrounding counties, it is quite certainly present. A local gardener reports having seen it at Melrose, but I have no specimens.

Family 106. HYDROPHYLLACEAE (Waterleaf Family)

797. **Hydrophyllum canadense** L. (Waterleaf)

Frequent in cool Porter soils, mountain glens. Specimens: By springs, Pearson's Falls, June 24, 1921; same locality, in flower, June 27, 1921; same locality, in fruit, May 11, 1926 (PT. nos. 660, 711, 2168).

798. **Hydrophyllum virginianum** L. (Waterleaf)

Noted, near Fishtop, in the summer of 1921.

799. **Phacelia hirsuta** Nutt.

Only one specimen of this is so far known, and that without further data than "Columbus, 1897 (Towns.).

800. **Phacelia bipinnatifida** Michx.

This pretty and unappreciated little flower is frequent under the shade of shrubs, taller herbs, stream-banks, etc., in the foothill region. Specimens: Side of Tryon range, April 23, 1897 (Towns.). Tryon, May, 1899 (Church.). Tryon Mt., April 21, 1911 (Day). Melrose, April 10, 1923 (PT. no. 1800).

Family 107. BORAGINACEAE (Borage Family)

801. **Myosotis virginica** (L.) BSP. (Scorpion Grass)
Lycopsis virginica L.
Myosotis verna Nutt.
Myosotis arvensis Torr.

The only specimen: Rocky Cliffs, near Tryon, May 4, 1897 (Bilt. Herb. no. 1360).

802. **Cynoglossum virginianum** L. (Wild Comfrey)
Cynoglossum amplexicaule Michx.

Common in rich glens of the foothills. Specimens: Tryon, May, 1899 (Church.). Columbus, April 27, 1899 (Towns.). Tryon Mt., May 2, 1911 (Day). Melrose, in fruit, June 27, 1921; "Valhalla," in flower, April 20, 1922, moist woods, Vaughan's Creek Glen, May 3, 1926 (PT. nos. 710, 1636, 2131).

In 1896 Miss Wright found the Hound's Tongue (*Cynoglossum officinale* L.) a pasture weed from Europe, in our area. No subsequent collector seems to have found it, though it is conspicuous enough, and it has probably died out, as the soil is not suited to it.

803. **Lappula virginiana** (L.). Greene (Stickseed)
Myosotis virginiana L.

Hackelia virginiana Johnston
Echinospermum virginicum Lehm.

Infrequent, in rich Porter soils, under the shade of mountain trees. Specimen: Tryon Mt., July 11, 1899 (Towns.).

804. **Lithospermum arvense** L. (Corn Gromwell)

A European waif, naturalized along the railroad track. Specimen: Tryon, in fruit, May 6, 1926 (PT. no. 2142). Probably well established. I have seen it here since 1919. The roots contain a purple dye.

805. **Onosmodium virginianum** (L.) A. DC. (False Gromwell)
Lithospermum virginianum L.
Onosmodium hispida Michx.

Infrequent, in mountain woods. Specimen: Mountain sides, near Columbus, in fruit, June 8, 1897 (Towns.).

806. **Echium vulgare** L. (Blue Devil)

This handsome harmful weed is of very recent advent in our area, not having been noted until 1927. Specimen: Tryon, July 10, 1927 (PT). It is doubtful if it will gain ground in our soils.

Family 108. VERBENACEAE (Vervain Family)

807. **Verbena officinalis** L. (European Vervain)

A foreign waif, naturalized along roadways. Specimen: Columbus, May 31, 1897 (Towns.).

808. **Verbena urticaefolia** L. (White Vervain)

Abundant as a native roadside weed, and also in deep woods. Specimens: Side of Tryon range, July 16, 1899 (Towns.). Tryon, June 20, 1921 (PT. no. 611).

809. **Verbena angustifolia** Michx. (Purple Vervain)

Specimen: Columbus, June 28, 1897 (Towns.). Apparently not common.

810. **Callicarpa americana** L. (French Mulberry)

A beautiful shrub, in fruit, rare with us. Specimen: Road to Chimney Rock, July 16, 1897 (Towns.).

Family 109. LABIATAE (Mint Family)

811. **Teucrium canadense** L. (Wood-sage)
Teucrium virginicum L.

Frequent in rich low ground. Specimen: Roadside between Landrum and Sandy Plains, June 16, 1897 (Towns.).

812. **Teucrium littorale** Bicknell (Wood Sage)

Frequent, in low alluvial soils, or dry open banks. Specimens: Along the Pacolet River, June 20, 1921; near "Lyncote," June 20, 1921 (PT. nos. 615, 627).

813. **Trichostema dichotomum** L. (Blue-curls)

In dry fields and around habitations, common. Specimens: Columbus, Aug. 21, 1897 (Towns.). Tryon, Aug. 27, 1921; Fishtop, Aug. 3, 1921 (PT. nos. 1406, 1426).

814. **Scutellaria ovata** Hill. (Skullcap)
Scutellaria versicolor Nutt.
Scutellaria cordifolia Muhl.

Common, dry woods and banks. Specimens: Columbus, also Spring Mt. Park, June 1897 (Towns. *Fide* Wiegand). "Lyncote" June 20, 1921 (PT. no. 623).

815. **Scutellaria incana** Muhl. (Skullcap)
Scutellaria canescens Nutt.
Scutellaria serrata Spreng.

Occasional in dry open ground. Specimens: Tryon, June 4, 1919 (PT. no. 0298).

816. **Scutellaria pilosa** Michx. (Skullcap)
Scutellaria pubescens Muhl.
Scutellaria ovalifolia Pers.

Scutellaria nemorosa Raf.
Scutellaria hirsuta Short

Very common in dry woods and fields. Specimens: Tryon, June 19, 1897 (Towns.). White Oak Mt., May 1918 (Millsp. no. 4195). Tryon, in fruit, Aug. 11, 1921 (PT. no. 1192). Six miles northeast of Millspring, on the Rutherfordton Road, May 26, 1927 (Wherry).

817. **Scutellaria serrata** Andr. (Skullcap)

Roadsides and moist banks, frequent. Specimens: Along the road north of Millspring, July 17, 1897 (Towns.). Fishtop, Aug. 31, 1921 (PT. no. 1431).

818. **Physostegia virginiana** (L.) Benth. (False Dragonhead)
Dracocephalum virginianum L.

This superb flower, much esteemed in horticulture, is infrequent, inhabiting only cool mountain woods. Specimens: Spring Mt. Park (Towns., without date). Hogback Mt., Sept. 17, 1927 (Wherry).

819. **Prunella vulgaris** L. (Heal-all. Carpenter's weed)

A recent treatment of this polymorphic species as it occurs in America has separated a native variety from the typical European species. This little summer plant is common both around habitations and in woods and fields.

820. **Glecoma hederacea** L. (Ground-Ivy. Gill-over-the-ground).
Nepeta hederacea Trevisan

A little European plant common about habitations. Specimen: Old walls, Tryon, April 10, 1919 (PT. no. 079). It often blooms in February.

821. **Nepeta Cataria** L. (Catnip)

A European barnyard waif. Specimen: Columbus, 1897 (Towns.).

822. **Lamium amplexicaule** L. (Henbit)

A common lawn waif, of Europe. Specimen: Tryon, May 8, 1919 (PT. no. 0201).

823. **Salvia lyrata** L. (Blue Sage)

Common in fields and woods, on the piedmont. Specimens: Columbus, May 22, 1897 (Towns.). Tryon, April 25, 1919 (Day). Tryon, April 16, 1922, and, in fruit, Aug. 12, and Aug. 23, 1921 (PT. nos. 1601, 1199, 1358.

824. **Salvia urticifolia** L. (Nettle-leaved Sage)

Frequent in fields and low woods, on the piedmont. Specimens: Road between Lynn and Columbus, June 3, 1897 (Towns.). Moist wooded bottom, Tryon, May 1918 (Millsp. no. 4.35).

825. **Monarda clinipodia** L. (Horse Mint)
Monarda glabra Lam.
Pycnanthemum monardella Michx.

In mountain woods. Specimens: Melrose, June 24, 1897 (Towns.). Melrose, June 24, 1921 (PT. no. 668).

826. **Monarda fistulosa** L. (Wild Bergamot)
Monarda longifolia Lam.
Monarda allophyllum Michx.
Monarda varians Barton

In mountain woods. Specimen: Melrose, June 27, 1921 (PT. no. 689).

827. **Monarda punctata** L. (Bee Balm)
Monarda lutea Michx.

Common in open sandy ground. Specimen: Road to Chimney Rock, Aug. 17, 1897 (Towns.).

Monarda didyma L., the splendid scarlet Oswego Tea, does not, I think, descend naturally into our altitudes, being a plant of the higher mountains, though it may be found on the little-known mountains of the northwestern corner of this county. It was, however set out on White Oak Mt. by Mr. Ludlom, and now grows there with all the appearance of a native.

828. **Stachys latidens** Small (Hedge Nettle)

Common throughout in shady soil. Specimens: Mountainsides, June 30, 1897 (Towns.). Tryon, June 20, and Aug. 29, 1921 (PT. nos. 624, 1416). Hogback Mt., Sept. 17, 1927 (Wherry).

829. **Hedeoma pulegioides** (L.) Pers. (American Pennyroyal)
Mellisa pulegioides L.
Cunila pulegioides L.

Frequent, in wet or dry ground, on the piedmont. Specimens: Beside a brook, Tryon, Aug. 25, 1921; edge of a field, Tryon, Aug. 27, 1921 (PT. nos. 1395, 1405).

830. **Pycnanthemum pycnanthemoides** (Leavenw.) Fernald (Basil)
Koellia pycnanthemoides Ktze.

Common in light woods and along open banks. Specimens: Spring Mt. Park, Aug. 1897 (Towns.). Along banks, Melrose, Aug. 8, 1921 (PT. no. 1116).

831. **Pycnanthemum flexuosum** (Walt.) BSP. (Basil)
Koellia flexuosa MacM.
Satureja thymus virginica L.
Ociganum flexuosum Walt.
Pycnanthemum linifolium Pursh

In dry ground, frequent. Specimen: Huston farm, near Columbus Aug. 17, 1897 (Towns.).

832. **Pycnanthemum montanum** Michx. (Mountain Mint)
Koellia montana Ktze.

This Appalachian endemic is common in mountain woods. Specimens: Spring Mt. Park, July 8, 1897 (Towns.). Summit of Tryon Mt., July 21, 1898 (Bilt. Herb. no. 749c). In cool deep mountain woods, Pearson's Falls, June 27, 1921 (Pt. no. 708, 713).

833. **Cunila origanoides** (L.) Britton (Dittany)
Satureja origanoides L.
Mappia origanoides House
Cunila mariana L.

This pretty aromatic little plant, conspicuous in winter for the curling crystals of ice which it shoots out on frosty mornings, is abundant in woods and thickets. Specimens: Rich cool mountain woods, in the pass between Hogback and Rocky Spur, (*Betula lenta* zone) Aug. 14, 1921; wet thickets, Tryon, Aug. 17, 1921 (PT. nos. 1261, 1262, 1269,

1289). Dry woods, Tryon, in young fruit, Sept. 15, 1926 (Hunnew. no. 9978). Pacolet Valley, in fruit, Nov. 21, 1926 (PT. no. 2358). Hogback Mt., Sept. 17, 1927 (Wherry).

834. **Lycopus sessilifolius** Gray (Water Hoarhound)

Frequent, moist banks and ground by streams. Specimen: Shaded banks above Melrose, June 24, 1921 (PT. no. 662).

835. **Lycopus virginicus** L. (Bugle Weed)

Frequent in rich moist soil. Specimen: Tryon, Aug. 20, 1921 (PT. no. 1305).

836. **Mentha viridis** L. (Spearmint)
Mentha spicata of auths., not L.
Mentha tenuis Michx.

Occasional escape; native of Europe and often cultivated in brooks around old farmsteads. Specimen: Farm brook near Tryon, Aug. 17, 1921 (PT. no. 1291).

837. **? Mentha viridis x M. citrata.**

My specimen no. 1556, collected Dec. 28, 1920, in the Pacolet Valley may be this rather well-known hybrid.

838. **Mentha citrata** L. (Bergamot Mint)

For many years near the summit of Hogback Mountain, there grew a large patch of a rather unusual mint, in the brook that forms the headwaters of the eastern fork of the Saluda river. This patch was well-known to mountain climbers in former times, but it seldom flowered. The station is now, I believe, destroyed by real-estate operations. Specimen: Aug. 14, 1921 (PT. no. 1253). Naturalized from Europe.

839. **Collinsonia canadensis** L. (Stoneroot. Rich-weed)
Collinsonia ovata Pursh

Not infrequent in mountain soils on the Porter loams. Specimens: Columbus, 1897 (Towns.). Vaughan's Gap between Hogback and Rocky Spur, Sept. 6, 1921 (PT. Nos. 1466, 1467).

840. **Micheliella verticillata** (Baldw.) Briq. (Horse Balm. Citronella)
Collinsonia verticillata Baldw.

This is the most interesting member of the mint family in our area; its appearance differing strikingly from all other mints of the region except *Collinsonia* from which it differs in having four stamens, and only four leaves, these in a false whorl at about the middle of the short (0.5–1 meter) stem; the flowers are salmon-pink, not yellow. They have the same rather shapeless but handsomely fringed lower lip. A clamminess or glandularity especially of the corolla is a marked feature, also the strong lemony odor. This plant ranges around the southern end of the Appalachians, penetrating the interior valleys; yet it is on the whole not a mountain, but a foothill, plant. Specimens: Foot of the Tryon range, May 10, 1899 (Towns.). Tryon, May 1918 (Millsp. no. 4040). In wet woods, "Valhalla," April 20, 1922; along Vaughan's Creek, in fruit, July 19, 1921 (PT. nos. 1631, 991, 990).

Family 110. SOLANACEAE (Potato Family)

841. **Datura Tatula** L. (Jimson Weed. Purple Thorn Apple)

A well-known poisonous weed of tropical American origin. So far it is not more than moderately common, chiefly affecting rubbish heaps around towns. Specimen: May 23, 1926 (PT. no. 2235).

842. **Physalis lanceolata** Michx. (Ground Cherry)

Occasional in dry clay or sand, on the piedmont. Chiefly a Middle Western species. Specimen: Tryon, May 1918 (Millsp. no. 4201).

843. **Physalis virginiana** Mill. var. **intermedia** Rydb. (Ground Cherry)

Occasional on dry hills and gravelly soil. Specimen: Tryon, May 1898 (Church.).

844. **Physalis heterophylla** Nees var. **ambigua** (Gray) Rydb. (Ground Cherry)

Dr. Wiegand kindly identified for me the following specimen in the Cornell herbarium: Side of Tryon Mt., June 30, 1899 (Towns. Specimen in fruit).

845. **Solanum carolinense** L. (Horse Nettle)

A common native weed. Specimen: Tryon, May 1918 (Millsp. no. 4151)

Family 111. SCROPHULARIACEAE (Foxglove Family)

846. **Verbascum Thapsus** L. (Common Mullein)

Common weed, naturalized from Europe in pastures. From early summer to winter. (Noted.)

847. **Verbascum Blattaria** L. var. **albiflorum** Ktze. (Moth Mullein)

Frequent weed, in pastures and along the roadsides naturalized from Europe. I have never found the typical yellow-flowered form in our area, though it is common in the Black Mountain range up to six thousand feet. Specimen: Lawns, Tryon, June 2, 1919 (PT. no. 0274).

848. **Mimulus ringens** L. (Monkey Flower)

Common in wet soil on the piedmont and even in the mountains. Specimens: Side of Tryon range, July 20, 1897 (Towns.). Millpond, July 24, 1921 (PT. no. 1055). Along the Saluda road, Sept. 18, 1927 (Pennell no. 14247).

849. **Mimulus alatus** Ait. (Monkey Flower)

In wet places; its frequency is not at present known, as there is but one collection to date: Warrior Mt., Sept. 18, 1927 (Pennell no. 14216).

850. **Gratiola virginiana** L. (Hedge Hyssop)
Gratiola sphaerocarpa Ell.
Gratiola megalocarpa Ell.
Gratiola carolinensis LeConte

Frequent, in standing water or sometimes in brooks. Specimens: Mountain brooks, May 19, 1897 (Towns.). Muddy ground on the Golf Links, Tryon, April 20, 1920 (PT. no. 1634).

851. **Ilysanthes dubia** (L.) Barnhart (False Pimpernel)
Gratiola dubia L.
Capraria gratioloides L.
Lindernia attenuata Muhl.

Frequent in brooks. Specimens: Mountain brooks, June 21, 1899. (Towns.). In a brook, Tryon, Aug. 25, 1921 (PT. no. 1398).

852. **Pentstemon canescens** Britton (Beardtongue)

Common in rocky woods and on rocky banks. Specimens: Spring Mt. Park, May 19, 1897 (Towns.). Pacolet Valley, May 22, 1919 (PT. no. 0239).

853. **Penstemon hirsutus** (L.) Willd. (Beardtongue)
Penstemon pubescens Ait.

Occasional in rocky woods. Specimen: Tryon, May 1899 (Church.).

854. **Penstemon laevigatus** Ait. (Beardtongue)
Chelone Penstemon L.
Penstemon Penstemon MacM.

Frequent in moist or rich soil. Specimens: Huston Farm, near Columbus, May 1897 (Towns.). Near the bridge over Walnut Creek, one mile inside Polk Co., on the Rutherfordton road. May 26, 1927 (Wherry).

855. **Penstemon Smallii** Heller (Beardtongue)

Typical *Penstemon Smallii* with large purplish flowers is perhaps less common in our area than was formerly thought by the present writer, since the segregation of the following species. It is therefore somewhat difficult to cite specimens, some of the examined long ago, before the segregation of the following species, and now widely distributed in distant herbaria. The following citations must be taken tentatively. Specimens: South ridge of Hogback Mt., May 27, 1927 (Wherry). Warrior Mt., in fruit, Sept. 18, 1927 (Pennell no. 14215). It grows in rocky woods and on rocky banks of the mountains and mountain valleys.

856. **Penstemon Brittanorum** Pennell (Beardtongue)

This is a smaller and paler flowered species (as I understand it) which appears to me to be much commoner in our area than the preceding. The following citations of specimens is made to the best of my understanding but must be considered tentative. Specimens: Side of Tryon Mt., May 19, 1897 (Towns.). Hogback Mt., Sept. 18, 1927

(Pennell no. 14241). Tryon, July 3, 1921; deep woods Kennedy's Farm, Tryon Mt., June 30, 1921; Pearson's Falls, deep mountain woods, May 11, 1926 (PT. nos. 823–827, 811, 2162).

857. **Chelone montana** Raf., var. **elatior** (Raf.) Pennell & Wherry. (Turtle Head)

Frequent in deep mountain woods. Specimens: Pearson's Falls, Sept. 12, 1921 (PT. no. 1499, A, B). Warrior Mt., in fruit, Sept. 18, 1927, and Hogback Mt. in fruit, Sept. 18 1927 (Pennell nos. 14211, 14227).

858. **Chelone Lyoni** Pursh (Turtle Head)

Common in mountain woods, in Porter's loam. Specimens: Spring Mt. Park, Aug. 10, 1897 (Towns.). Deep cool woods, Pearson's Falls, Sept. 3, 1921; rich soil, Fishtop, Aug. 31, 1921 (PT. nos. 1453, 1430). Along the Saluda road, Sept. 18, 1927 (Pennell no. 14246).

Forma **latifolia** (Ell.) Pennell. The following specimens may be cited: Warrior Mt., Sept. 18, 1927, and, same date, Hogback Mt., (Pennell nos. 14212, 14213, 14223). Probably more widespread, as it occurs in Rutherford County just beyond the northernmost portion of our county.

859. **Scropularia marilandica** L. (Figwort)

Common in mountain woods. Specimens: Rich glen, Melrose, Aug. 8, 1921 (PT. no. 1102). Spring Mt. Park, Aug. 6, 1897 (Towns.). On Hogback Mt., Sept. 18, 1927 (Pennell 14230).

860. **Linaria canadensis** (L.) Dumont (Toadflax)
Antirrhinum canadense L.

Frequent in cultivated fields and alluvial sands, to the foot of the mountains. Specimens: Tryon, April 16, 1922, and May 23, 1926 (PT. nos. 1605, 2254).

861. **Linaria vulgaris** Mill. (Butter and Eggs. Ramstead)
Antirrhinum Linaria L.
Linaria Linaria Karst.

A common wayside weed, naturalized from Europe. Summer.

862. **Linaria Cymbalaria** (L.) Mill. (Kenilworth or Coliseum Ivy)
Antirrhinum Cymbalaria L.
Cymbalaria hederacea S. F. Gray
Cymbalaria muralis Gaertn.; Mey & Scherb.
Cymbalaria Cymbalaria Wettst.

Introduced from Europe, cultivated, and escaping to walls and rocks. I think it can confidently be asserted that the original introduction of this pretty little mural plant was made about thirty years ago at "Lyncote." It is spreading only slowly. Specimen: Tryon, May 1918 (Millsp. no. 4044).

863. **Veronica serpyllifolia** L. (Speedwell)

Infrequent, in wet grass or woodland brooksides. Perhaps naturalized from Europe. Specimen: Vaughan's Creek, April 29, 1919 (PT. no. 0173).

864. **Veronica arvensis** L. (Corn Speedwell)

Naturalized from Europe, a lawn weed. Specimen: Tryon, April 28, 1919 (PT. no. 0156).

865. **Veronica peregrina** L. var. **xalapensis** (H. B. K.) Pennell (Neckweed)

Possibly naturalized from Europe. A lawn weed.

866. **Aureolaria pedicularia** (L.) Raf. var. **austromantana** Pennell (Yellow False Foxglove)

This endemic variety of the southern Appalachians is frequent in our area in the mountains and foothill woods, usually in well drained soil. Specimen: Tryon, Aug. 12, 1921 (PT. nos. 1209, A).

867. **Aureolaria flava** (L.) Farwell (Yellow False Foxglove)
Gerardia flava L.
Aureolaria glauca Eddy; Raf.
Agalinus glauca Blake
Gerardia virginica Britton
Dasystoma virginica Britton
Gerardia quercifolia Pursh

Frequent in dry woods, mountains and foothills. Specimens: Tryon, Sept. 15, 1926 (Hunnew. no. 9997). Hogback Mt., Sept. 18, 1927; along the Saluda River, Sept, 29, 1927 (Pennell nos. 14238, 14242).

868. **Aureolaria laevigata** Raf. (Yellow False Foxglove)
Gerardia laevigata Raf.

Frequent in rocky woods and dry soil, mountains and foothills. Specimens: Spring Mt. Park., Aug. 25, 1897 (Towns.). Tryon, Sept. 18, 1927; Rocky Spur, Sept. 18, 1927 (Pennell nos. 14209, 14225).

869. **Aureolaria virginica** (L.) Pennell (Yellow False Foxglove)
Rhinanthus virginicus L.
Aureolaria villosa Raf.
Gerardia villosa Muhl.
Gerardia virginica Ktze.
Dasystoma pubescens Benth.
Dasystoma brachycarpa Small

Frequent in dry woods, mountains and foothills. Specimens: Tryon, Aug. 11 and 12, 1921 (PT. nos. 1172, 1208, A). Rocky Spur, Sept. 18, 1928, same date, Melrose (Pennell nos. 14224, 14219).

870. **Agalinus tenuifolius** (Vahl.) Raf. (Purple False Foxglove)
Gerardia tenuifolia Vahl.

Up to the present this seems to be the only member of this genus which anyone has found in our area. It is common in open sandy ground on the piedmont and sometimes in the mountains, as an autumn flower. Specimens: Spring Mt. Park. Aug. 25, 1897 (Towns.). Open ground and woods, Vaughan's Gap between Hogback and Rocky Spur, Sept. 6, 1921; Melrose, Sept. 3, 1921; Lynn, Nov. 1, 1926 (PT. nos. 1487, 1455, 2421). Tryon, Sept. 18, 1927, and, same date, Melrose Mt., and Rocky Spur (Pennell, 14208, 14217, 14223).

871. **Buchnera americana** L. (Blue Hearts)

Sandy ground, wet or dry, on the piedmont. Specimen: Tryon, Aug. 11, 1921 (PT. no. 1190).

872. **Castilleja coccinea** (L.) Spreng. (Scarlet Painted Cup).
Bartsia coccinea L.

In low moist sands, or very frequently on rocks beside waterfalls, in the mountains and sandy streams at the foot of the mountains. Infrequent or at least local, but very showy where occurring. Specimens: Shunkawawkin Falls, April 15, 1897 (Towns.). Waterfalls, Pacolet Valley, April 20, 1923 (PT. no. 1860). Tryon Mt., April 26, 1911 (Day). Also blooms the first weeks of May.

873. **Pedicularis canadensis** L. (Wood Betony)

Common in mountain deciduous woods. Specimens: Piney Mt., April 20, 1922 (PT. no. 1660). Hogback Mt. (in fruit) Sept. 18, 1927 (Pennell no. 14233). Tryon Mt., April 9, 1928 (Kimber).

874. **Melampyrum lineare** Lam. var. **latifolium** (Muhl.) Beauvard (Cow Wheat)

Infrequent, in mountain deciduous woods. June-Sept. (Noted.)

Family 112. OROBANCHACEAE (Broom-rape Family)

875. **Epifagus virginiana** (L.) Bart. (Beech-drops.)
Leptanmium virginianum Raf.
Orobanche virginiana L.
Epifagus americana Nutt.

Common as a parasite on beech roots. Specimens: Columbus, Oct. 1897 (Towns.). "Pearson's Falls," Sept. 3, 1921 (in fruit); Dec. 27, 1920 (PT. nos. 1447, 1586).

876. **Conopholis americana** (L. f.) Wallr. (Squaw-root)
Orobanche americana L. f.

Parasitic, chiefly on oaks. Frequent locally, and in some years apparently abundant throughout its range, as in 1921; in other years very scarce. Specimens: In a glen, "Skuyuka," April 17, 1897 (Towns.). In rich woods, "Valhalla" in fruit, Aug. 29, 1921, and, same locality, in flower, April 19, 1922 (PT. nos. 1422, 1642).

877. **Aphyllon uniflorum** (L.) T. & G. (Cance -root)
Orobanche uniflora L.
Thalesia uniflora Britton

Frequent in rich cool woods, sometimes parasitic on beeches. Specimens: Side of Tryon range, 1897 (Towns.). "Valhalla", April 20, 1922 (PT. no. 1635).

Family 113. BIGNONIACEAE (Catalpa Family)

878. **Paulownia tomentosa** (Thunb.) Baill. (Princess Tree. Chinese Catalpa)
Bignonia tomentosa Thunb.
Paulownia imperialis Sieb. & Zucc.

Ordinarily this tree has been considered a member of the *Scrophulariaceae*, but Dr. Pennell, our foremost specialist in this group, in private correspondence with the writer, agrees that it should be excluded from that family. On account of its winged seeds and woody habit, it must certainly belong to the *Bignoniaceae*. Introduced from China, it is one of our commonest ornamental trees and is thoroughly established, even on the mountain sides in natural forest. Its sucker and sapling leaves are the largest foliage in our flora. Specimen: Tryon, in flower, May 23; in fruit, Dec. 28, 1920 (PT. no. 1084).

Catalpa bignonioides Walt., a native of the Gulf Coast, is much cultivated and has a slight tendency to escape.

879. **Bignonia radicans** L. (Trumpet Vine)
Tecoma radicans Juss.
Campsis radicans Seem.

Abundant in sunny and open soil, sometimes in the mountains, and very commonly on open red clay banks, in fallow fields, etc. Also cultivated. Specimen: Tryon, July 23, 1921 (PT. no. 1046).

880. **Doxantha capreolata** (L.) Miers (Cross Vine)
Bignonia capreolata L.
Bignonia crucigera L., in part
Anisostichus capreolata Bur.

Frequent in glens along the piedmont, and very attractive. Specimens: Vaughan's Creek glen, May 14, 1911 (Day). Same habitat April 20, 1922 (PT. no. 1690). A dark red variety, very handsome, is in cultivation in Tryon. I have not seen it in the wild.

Family 114. ACANTHACEAE (Acanthus Family)

881. **Ruellia carolinensis** (Walt). Steud
Ruellia ciliosa Pursh

Our only member of this tropical family is this curious and not unattractive little flower which is frequent on the piedmont, in moist open ground, especially on the red clays. Specimens: Tryon, July 22, 1897 (Towns.). "Valhalla", June 20, and Tryon, Aug. 23, 1921 (PT. nos. 616, 617, 126, 1351).

Family 115. PHRYMACEAE (Lopseed Family)

882. **Phryma Leptostachya** L. (Lopseed)

Frequent on the Tryon range, in Porter's loam and deep mountain woods. Specimens: Side of Tryon range, June 21, 1899 (Towns.). Kennedy's Farm, Tryon Mt., June 30, and "Skuyuka", July 21, 1921 (PT. nos. 808, 809, 1016). This is one of the clearest examples of the plants common to eastern Asia and eastern U. S. A.

Family 116. PLANTAGINACEAE (Plantain Family)

883. **Plantago Rugelii** Dcne. (Common Plantain)

This common native weed is found only in meadows and around the habitations and communication lines of man. I have examined many specimens in the endeavor to find *Plantago major*, which is similar and very common elsewhere but so far I have never found it in our area.

884. **Plantago lanceolata** L. (English Plantain)

Naturalized from Europe and common around houses and along roads. Specimen: Tryon, May 23, 1926 (PT. no. 2217).

885. **Plantago aristata** Michx. (Bottle-brush Plantain)

Frequent in open fields and dry soil, on the piedmont. Specimens: "Huston Farm" near Columbus, June 26, 1897 (Towns.). Tryon, May 1899 (Church.).

886. **Plantago virginica** L. (Plantain)

Common, throughout, both in thickets, along stream banks, roadways, in lawns, on mountain cliffs, etc. Specimens: Tryon, April 16, 1897 (Towns.). Fissures in a high bare cliff, Saluda, May 1918 (Millsp. 4120).

Family 117. RUBIACEAE (Madder Family)

887. **Houstonia caerulea** L. (Bluets. Quaker Ladies. Innocence)
Houstonia Linnaei var. *elatior* Michx.

Common throughout, especially by streams and rills in partial shade, but sometimes in open fields; less frequent on the mountains. Specimens: Vaughan's Creek, April 14, 1919 (Day). Dry soil, Tryon, April 10, 1923 (PT. no. 1824).

888. **Houstonia minor** (Michx.) Britton (Little Bluets)
Houstonia Linnaei var. *minor* Michx.
Houstonia patens Ell.

Not infrequent along streams and rills, often with the preceding but escaping notice. Specimen: Tryon, April 3, 1928 (Day).

889. **Houstonia serpyllifolia** Michx. (Mountain Bluets)

This beautiful little flower, an Appalachian endemic with delicate corollas of a deep gentian blue, which makes such a fine sight on the mountains meadows of the the Mt. Mitchell range at 5000 feet, is infrequent in our area. It is found in rich soil of deep, cool mountain woods. Specimens: Tryon Mt., May 1918 (Millsp. no. 4094). Tryon Mt., April 5, and May 1, 1019 (Day).

890. **Houstonia purpurea** L.

Very common throughout, especially in light dry woods. Specimens: Fox Mountain, May 10, 1897 (Towns.). Melrose, May, 1899 (Church.). Pearson's Falls, June 24, 1921 (PT. no. 659).

Var. **pubescens** Britton. Common, usually with the type. Specimens: Godshaw Hill, Tryon, May 23, 1926 (PT. no. 2237). Walnut Creek, one mile inside Polk County, Rutherfordton Road, May 26, 1927 (Wherry).

891. **Houstonia lanceolata** (Poir.) Britton

Infrequent, in dry piedmont woods. Specimen: Tryon, April 25 1919 (PT. no. 0143).

892. **Houstonia ciliolata** Torr.

Frequent in dry woods. Specimens: Tryon, May 18, 1911 (Day). "The Shoals," May 1918 (Millsp. no. 4087).

893. **Oldenlandia uniflora** L.
Oldenlandia glomerata Michx.
Hedyotis glomerata Ell.

Rather infrequent, on rocks and along rocky stream banks. Specimen: Tryon, Aug. 23, 1921 (PT. no. 1350).

894. **Cephalanthus occidentalis** L. (Button bush)

Not infrequent in marshy ground and low meadows in the eastern part of the county; rare in the western part. Specimens: Along Skunkawawkin Creek, west of Columbus, June 29, 1897 (Towns.). In wet ground, "The Shoals," Aug. 20, 1921 (PT. no. 1329).

895. **Mitchella repens** L. (Partridge Berry)

Common in woods throughout, especially the foothills. Specimens: Columbus, May 30, 1899 (Towns.). Tryon, May 23, 1926 (PT. no. 2251). The edible but insipid berries are rather conspicuous through summer and autumn, and are much eaten by little wood birds.

896. **Diodia virginiana** L. (Buttonweed)

In low wet meadows, mucky ground around millponds, etc., frequent. Specimens: "Huston Farm" near Columbus, July 9, 1897 (Towns.). Low grounds along the Pacolet. June 20, 1921 (PT. no. 625). In a meadow, Tryon, both in flower and fruit, Sept. 15, 1926 (Hunnew. 9947).

897. **Diodia teres** Walt. (Buttonweed)
Spermacoce diodina Michx.

Sandy wet ground or in pastures, frequent. Specimens: Columbus June 23, 1897 (Towns.). Tryon, in fruit, July 19, 1921 (PT. no. 1000). Both this and the preceding have a delightful fragrance.

898. **Galium Aparine** L. (Cleavers. Goose Grass)

In rich or moist shaded ground, occasional, chiefly in the mountains. Specimen: On wet rocks in deep shade, Melrose, Aug. 8, 1921 (PT. no. 1115).

899. **Galium pilosum** Ait. (Bedstraw)
Galium puncticulosum Michx.

Common in dry thickets. The flowers seem frequently to be red. Specimens: Columbus, June 17, 1899 (Towns.). Tryon, July 19 and Aug. 17, 1921 (PT. nos. 975, 1292).

900. **Galium circaezans** Michx. (Wild Liquorice)
Galium boreale Walt.

In rich or sterile woods, frequent. Specimens: Banks of Shunkawawkin Creek, Columbus, June 14, 1897 (Towns.). In sterile pine woods, Tryon, June 29, 1921 (PT. no. 762).

901. **Galium latifolium** Michx. (Bedstraw)

This Appalachian endemic is frequent in mountain woods. Specimens: Side of the Tryon range, June 14, 1899 (Towns.). Deep woods, Pearson's Falls, June 24, 1921 (PT. nos. 657, 658).

902. **Galium Claytoni** Michx. (Bedstraw)
Galium trifidum Pursh

In marshes and damp places. Specimen: Along streams, Tryon, May 1899 (Church.). Marsh near Columbus, June 20, 1899 (Towns.).

903. **Galium triflorum** Michx. (Sweet-scented Bedstraw)
Galium brachiatum Pursh

This little plant which is sweet-scented in drying has a range including British Columbia, Greenland, Europe and northern Asia; it also ranges southward in the mountains almost to Mexico. It seems to have been collected but once in our area. Specimen: Side of Tryon range, July 11, 1899 (Towns.).

Family 118. LONICERACEAE (Honeysuckle Family)

904. **Sambucus canadensis** L. (Elder)

Not frequent in the foothill region, but commoner in the eastern part of the county and occasional in the mountains. Marshy ground and low meadows. Specimens: Columbus, June 10, 1899 (Towns.). In a marsh on top of Hogback Mountain, headwaters of the Saluda River, in fruit, Aug. 14, 1921 (PT. no. 1219, A).

905. **Viburnum acerifolium** L. (Arrow-wood. Dockmackie)

Common in deciduous woods, from the low grounds to the highest mountains. Specimens: Saluda, May, 1899 (Church.). "Sunset Rock" Tryon Mt., May 25, 1899 (Towns.). "Skuyuka" Tryon Mt., in fruit, July 21, 1921 (PT. no. 1027). Leaves and berries both make a beautiful showing in autumn.

906. **Viburnum nudum** L. (Smooth Viburnum)

Common on the piedmont, along streams. Specimens: Columbus, June 6, 1899 (Towns.). Tryon, in fruit, Aug. 17, 1921 (PT. nos. 1277, 1278, 1281).

907. **Viburnum prunifolium** L. (Black Haw)

Abundant along streams in the *Betula nigra* zone. Often large enough to rank as a tree. Specimens: Foot of Tryon Mt., June 8, 1897 (Towns.). Along streams, Columbus, April 15, 1923, and in wet thickets, Tryon, in fruit, Aug. 17, 1921 (PT. nos. 1851, 1280, 1282). Banks of the Green River, April 26, 1928 (Kimber).

908. **Viburnum rufidulum** Raf. (Rusty Viburnum)
Viburnum rufotomentosum Small

Common in woods and thickets, chiefly in the mountains. Specimens: Side of Tryon range, May 5, 1897 (Towns.). Tryon Mt., May 14, 1911 (Day). "Skuyuka" May, 1899 (Church.). "Skuyuka," in fruit, July 21, 1921 (PT. nos. 1025, 1026). Pacolet gorge, May 5, 1928 (Kimber).

909. **Triosteum perfoliatum** L. (Tinker's Weed. Wild Coffee)
Triosteum majus Michx.

Occasional in mountain meadows or woods. Specimen: Tryon range, May 25, 1899 (Towns.). "Rickshaven," Tryon Peak, June 4, 1919 (PT. no. 0318). Miss Wright reports it from Log Cabin Inn.

910. **Symphoricarpos orbiculatus** Moench. (Indian Currant. Coral Berry)
Symphoricarpos Symphoricarpos MacM.
Symphoricarpos vulgaris Michx.
Symphoria glomerata Pursh

This plant, often cultivated, especially for its pretty red berries, has been collected here just once, and represents a somewhat rare "find," if native. Just possibly it may have escaped, as it was found within the town of Tryon, but in woods. Specimen: "Glen Walden," in fruit, Jan. 22, 1919 (Day).

Symphoricarpos albus (L.) Blake (*S. racemosus* Michx.) the snowberry, so commonly cultivated, shows a slight tendency to naturalize itself; it is native on limestone of the northern and western states. Var. *laevigatus* (Fernald) Blake may, just possibly, occur as a native. I found a shrub in Vaughan's Creek glen, in sterile state, that may belong here. Specimen: May 3, 1926 (PT. no. 2127).

911. **Lonicera japonica** Thunb. (Japanese Honeysuckle)

There is no more successfully naturalized foreign plant than the ubiquitous and heavy-scented Japanese Honeysuckle. It blooms from May to October, and while harmful in gardens, it covers many unsightly spots attractively.

912. **Lonicera sempervirens** L. (Trumpet Honeysuckle)
Phenianthus sempervirens Raf.
Pericyclamenum sempervirens Mill.
Caprifolium sempervirens Michx.

This beautiful vine while not rare is sporadic in appearance. Some of our specimens have thin, deciduous leaves, and some evergreen and thick leaves. It is also cultivated in our area. Specimens: Spring Mt. Park, June 1, 1899 (Towns.). Tryon, May, 1918 (Millsp. no. 4063).

Var **hirsutula** Rehder.

This southern variety is frequent. Specimens: Spring Mt. Park, May 25, 1899 (Towns.). Lynn, and "Skuyuka" May, 1899 (Church.).

913. **Lonicera dioica** L. (Honeysuckle)
Lonicera glauca Hill.
Caprifolium bracteosum Michx.
Caprifolium parviflorum Pursh

Rocky woods in the mountains, rare. Specimen: "Sunset Rock" Tryon Mt., May 25, 1899 (Towns.).

914. **Lonicera flava** Sims. (Yellow Honeysuckle)
Caprifolium Fraseri Pursh
Lonicera Fraseri Eaton

This beautiful plant of the Southern Appalachians, while by no means uncommon in this state, is sporadic in its distribution. Our region however has long been noted for the common occurrence of this vine. Specimens: Tryon, April 28, and mountains above Columbus, May 5, 1897 (Towns.). Tryon, May 1899 (Church.). Tryon, April 30, 1911 (Day). In the dry woods of the ridge connecting Piney Mt. and Melrose Pk., April 20, 1922 (PT. no. 1640).

Family 119. VALERIANACEAE (Valerian Family)

915. **Valerianella Locusta** (L.) Betcke (Lamb's Lettuce)
Valeriana Locusta L.
Valerianella olitoria Poll.

This dainty little herb, popular in gardens of long ago, and introduced from Europe, is still sometimes cultivated in country districts. It appeared spontaneously in lawns of Tryon some years ago, constituting the first record of its naturalization in the southern states. Specimen: Tryon, May 6, 1926 (PT. no. 2143).

Family 120. CUCURBITACEAE (Gourd Family)

916. **Melothria pendula** L.

This solitary representative of a genus chiefly tropical must be very rare, as it has not been collected since its first discovery thirty-three years ago. Specimen: Side of the Tryon range, Aug. 9, 1897 (Towns.).

Familiar cultivated plants of the region are the squashes, *Cucurbita Pepo, C. moschata, C. maxima;* the gourd, *Lagenaria leucantha* (*L. vulgaris*); the watermelon *Citrullus vulgaris;* the melon, *Cucumis melo;* all of which show some tendency to escape from cultivation.

Family 121. CAMPANULACEAE (Bluebell Family)

917. **Specularia perfoliata** (L.) A. DC. (Venus' Looking-glass)
Legouzia perfoliata Britton

Common in fields, and even as a weed, chiefly on the piedmont, but also in mountain meadows. Specimens: Tryon, May 7, 1919 (Day). Tryon, May 23, 1926 (PT. no. 2220).

918. **Campanula americana** L. (Tall Bellflower)

Common in the shaded Porter's soils or the mountains. Absent from the piedmont. Specimens: Side of Tryon range, July 29, 1897 (Towns.). Whiteoak Mt., July 21, 1921 (PT. nos. 1021, 1022). Howard's Gap, July 25, 1921 (PT. no. 1074).

919. **Campanula divaricata** Michx. (Mountain Bluebells)

A pretty little Appalachian endemic, frequent in late summer in deep mountain woods. Specimens: Tryon Peak, Aug. 9, 1897 (Towns.). On dripping rocks, Aug. 20, 1921 (PT. no. 1096).

The European *Campanula medium* (Canterbury Bell) has been found as a sporadic escape, but is perhaps not established.

Family 122. LOBELIACEAE (Lobelia Family)

920. **Lobelia inflata** L. (Indian Tobacco)

A common little native weed; very poisonous. Specimen: Meadows near Tryon, June 29, 1921 (PT. no. 754).

921. **Lobelia amoena** Michx.

Although Gray's "Manual" says of this "in swamps," it is with us a plant of mountain woods. Specimens: Spring Mt. Park, October, 1897 (Towns.). In cool mountain woods, Pearson's Falls, Sept. 3, 1921 (PT. no. 1448).

Var. **glandulifera** Gray.

Common with the type. Specimens: Rich glens, Melrose, Aug. 8, 1921; Pearson's Falls, Sept. 3, 1921 (PT. nos. 113, 1449, 1450).

922. **Lobelia puberula** Michx.

Moist sandy grounds on the piedmont. Specimen: Columbus, Oct. 1897 (Towns.).

923. **Lobelia leptostachya** A. DC.

Common in mountain or foothill woods. Specimens: Columbus, Oct., 1897 (Towns.). Rich woods, Tryon Mt., June 30, 1921; Whiteoak Mt., 2600 ft., July 21, 1921 (PT. nos. 805, 1008).

924. **Lobelia cardinalis** L. (Cardinal Flower)

This resplendent red flower, much sought in cultivation, is not infrequent in muddy ground, around millponds, and along streams of the piedmont. Absent from the mountains. Specimens: Millspring, Aug, 11, 1899 (Towns.). Tryon, Aug. 23, 1921 (PT. no. 1353, A.)

VEGETATION OF THE BLACK MOUNTAINS OF NORTH CAROLINA: AN ECOLOGICAL STUDY

By JOHN H. DAVIS, JR.

PLATES 30 AND 31

The forested areas of the Southern Appalachian Mountains have been studied from various standpoints since the early days of exploration. Many botanists have visited that part of the region which lies in western North Carolina, but most of their studies have been descriptive and systematic in character and little attention has been paid to the quantitive ecological aspects of the vegetation. The present paper is a summary of studies made in the Black Mountain area of this Appalachian region during the past six years. The study has included a careful analysis of the vegetation to determine the major and minor plant communities of which it is composed. Many instrumental studies of the environmental factors at play in determining these community types have been made, but only a brief analysis of the vegetation and its most essential floristic characteristics will be presented here.

The writer wishes to acknowledge at this time his indebtedness to Professors George D. Fulcher, Henry C. Cowles and W. L. Porter, for many favors. Mr. T. G. Harbison, Dr. Hugo L. Blomquist, Mr. Kenneth K. Mackenzie, Mr. Jason R. Swallen and Miss Mildred Irwin have aided in the identification of species. The staff of the Appalachian Forest Experiment Station at Asheville has assisted in many ways.

THE REGION

Geographically the Black Mountains are a part of the Blue Ridge system of the Southern Appalachians. They are a short range that includes some of the loftiest peaks in eastern America, of which Mount Mitchell (6,684 ft.) is the highest. The range is located about 20 miles east-northeast of Asheville, North Carolina, 35° 45′ north and 82° 15′ west. The area of this study includes this range and the adjacent ridges and valleys. Aside from a few square miles in the Asheville basin it lies wholly within the area covered by the Mount Mitchell Quadrangle of the United States Geological Survey (15), and most of the

observations were made within the Mount Mitchell unit of the Pisgah National Forest and in the Mount Mitchell State Park.

The area studied covers about 150,000 acres and is sufficiently varied and extensive to furnish adequate contrast between all types of topography and vegetation common to the region as a whole.

The topographic features are typical of the Southern Appalachians. Narrow valleys separate irregular ridges and few high ranges of no great length rise out of the general mass so imperceptibly that their peaks are often not observable at any great distance. Precipitous slopes and rough irregular topography are not common as this is a region of long erosion. There are very few rock outcrops and sheer cliffs are found only along a few streams. By reason of the fact that these mountains are very old they have become regular in outline and except for differences in degree and aspect of slope and in elevation, vary little one from another.

The vegetation is affected by the general topography and certain forest types have been classified as valley or cove types, slope types, and ridge or peak types. Ecologically the differences in aspect of slope and in altitude are the most important topographic features affording in many instances a basis for classification of the plant communities.

THE VEGETATION

The following ecological classification of the vegetation of this area is on the general basis of composition of the plant populations of the various communities. This was done only after adequate systematic studieshad been made and quadrat and other quantitative methods of vegetational study employed. Although over 700 species all told have been identified and although a great deal of information as to their distribution has been gained, no attempt will be made to describe the flora of the area in detail. The most essential floristic components of each forest, shrub and herbaceous community may be obtained from the short list of the dominant, most frequent and most exclusive species which is given with the descriptions of the communities. An obvious intergradation of the various communities may be seen from a comparative study of the species list of each community.

It is difficult to draw a definite line of division between one type of community and another, but for convenience in study and analysis, the area has been divided into major and minor plant communities, the division being based on the best evidence so far obtained as to the integrity of the communities as distinct vegetational groupings.

The major plant communities.

It is difficult to establish major divisions of the vegetation in a region displaying such an admixture of forms where the forests intergrade so freely. Certain essential forest types or formations have been distinguished by foresters. The best of these are the forest type classifications of the Society of American Foresters (12), and the classifications of Livingston and Shreve (9), Shantz and Zon (10), and Holmes (8), Harshberger (7), and Wells (16), have given ecological classifications and many other botanists have recognized and described certain major communities and vegetational zones.

If, by major plant communities, we understand those larger plant aggregations, distinct in physiognomy, with a rather definite floristic composition and of general and widespread occurrence in the area, there are three such groupings to be found here above the broader valleys and upper piedmont. These may be called formations or forest types as this area is essentially a forest one. They are:

1. The spruce-fir forest formation, of high mountain slopes and ridges.
2. The northern hardwood forest formation, of intermediate slopes, ridges and coves.
3. The Appalachian forest formation of lower coves, slopes and ridges.

Each of these formations is readily divisible into lesser or minor communities for the formation is essentially a complex of many communities of varying plant populations with usually one dominant type called the climax association. The climax communities are the highest expression of the vegetation developed under the prevailing climatic and edaphic conditions in each formation and they give the most distinctive character to the formation. The other communities, which are usually of less extent, are not so obviously a part of the formation but are included for they are either successional stages in the development of the climax type or they are divergencies or variants from the climax type due to topographic or edaphic conditions. The minor communities are treated as associations, consociations, societies and clans in the commonly accepted use of these terms.

THE SPRUCE-FIR FOREST FORMATION

Above 6,000 feet on the warmer and southfacing slopes and above 5,500 feet on the cooler and northfacing slopes a dense forest composed essentially of red spruce, *Picea rubra* and Fraser's fir, *Abies fraseri*, extends to the summits of the highest peaks with only a few breaks

which occur mainly along the ridges and in the gaps as mountain meadows or forest inclusions. This forest has now been so cut over that little of the original stand is left. However, much of the original forest was observed by the writer and enough of it remains in the National Forest and State Park to afford ample material for study. The greatest extent of this forest, both the original and present stand, is along the Black Mountain range.

This formation is the southern extension along the high mountains of Eastern North America of the northern conifer forest. In general character and in its floristic composition it closely resembles the Canadian boreal forest. Where it has been extensively logged interesting secondary successional communities have replaced the original forest. Towards its lower limits it fuses with the northern hardwood forest, and isolated or thinned stands of spruce and fir extend to much lower levels than those give. On exposed peaks and at the highest altitudes the trees often assume sub-alpine growth form indicating approach to a timber line. Core (3) in West Virginia has found sub-alpine forms at lower elveations than these.

THE NORTHERN HARDWOOD FOREST FORMATION

This formation is the most limited of the three, occurring as a narrow belt between the spruce-fir and the Appalachian forest. In general, it is found between the altitudes of 4,500 and 5,500 feet, but it may occur at lower altitudes. Along some of the ranges it is almost completely absent. On the south and dry slopes there may be direct transition from spruce-fir to Appalachian forest without any intermediate zone. At its upper limits and especially along exposed ridges, the formation gives way to treeless or sub-alpine communities which are called mountain meadows or *balds* and *orchards* or savannas respectively. These interesting physiographic communities have attracted much attention and will be considered in detail.

The dominant tree species of the formation are the beech, *Fagus grandifolia*, the eastern buckeye, *Aesculus octandra*, the yellow birch, *Betula lutea*, the hard maple, *Acer saccharum*, the northern red oak *Quercus borealis*, and the basswoods, *Tilia* spp. Many other hardwood species are associated as codominants. No conifer is either a frequent or typical member of the formation. Consociations and variants from the general type are common within the formation. Communities of this formation are best distinguished from those of the Appalachian forma-

tion by the absence of *Castanea dentata*, *Tsuga canadensis* and *Liriodendron tulipifera* as dominants.

The minor communities of this hardwood forest are more varied than those of the spruce-fir. The climax association is limited to the coves, upper benches and moist slopes. In floristic composition and general ecologic nature this formation is comparable to the hardwood forests of the more northern states. It is, like the spruce-fir forest, an extention southward along the mountains of boreal vegetation.

THE APPALACHIAN FOREST FORMATION

This forest is a deciduous-conifer forest in which the deciduous species predominate. It is composed of a number of southern hardwoods, that reach their highest development in this section of the Southern Appalachians, and thus well deserves the name given it. Its range is from the piedmont and plateau types at 1,500 to 2,500 feet to the northern hardwood or spruce-fir forests. It is the montane forest type of the area. The piedmont and plateau types may be considered basal and the northern hardwood and spruce-fir forests may be considered boreal and even sub-alpine in places.

Over 25 tree species are commonly associated in this forest but the chestnut, *Castanea dentata*, is the most important and typical. Its presence as a dominant in any association characterizes that community as a part of the Appalachian forest. The other dominants and codominants are too numerous to allow detailed description but among the most typical are *Liriodendron tulipifera*, *Quercus montana*, *Q. borealis*, *Q. alba*. The conifers are only locally abundant growing in two entirely different situations. The Canada hemlock, *Tsuga canadensis*, and occasionally the white pine, *Pinus strobus*, are common to the coves and lower protected slopes, while the mountain pines, *Pinus rigida* and *P. pungens*, and the rare Carolina hemlock, *Tsuga caroliniana*, occur on the xeric slopes and ridges or in the pioneer communities.

This formation is the most extensive of the three covering over seventy percent of the forested area studied. It is readily divisible into minor communities on a topographic basis, as the cove climax, the mesic slope, and the xeric slope and ridge associations.

The minor plant communities

From a review of the above it will be seen that the vegetation as a whole is divisible into three altitude belts, formations or life zones, but

only careful analysis of the minor communities will bring out the ecological characteristics of the vegetation of the whole area.

The floristic composition of the communities, given in the tables, indicates the abundance or frequency, the constancy and exclusiveness of the most important species in the manner suggested by Tansley and Chipp (14). No attempt is made to give the results obtained from quadrat and strip studies as space forbids and a general but accurate impression of the plant population may be gained in the manner employed.

In all tables of floristic composition the following symbols are used:

F—High percentage of frequency or abundance
f—Moderate percentage of frequency or abundance
C—Very constant component
c—Fairly constant component
E—Exclusiveness of a marked degree
e—Exclusiveness of a moderate degree
L—Locally abundant as a consociation or clan
R—Rare but significant or very exclusive
p or a blank—present but not abundant or significant

Species are listed in approximate order of their abundance or index value in the community and not in phylogenetic order. The nomenclature is that of Sudworth's (13) Check list of the forest trees of the United States, for the tree species, and Gray's (6) New Manual of Botany, for all the other ferns and seed plants except for some southern forms for which the terms of Small's (11) manual are employed.

The spruce-fir climax association.

The climax and dominant community of the spruce-fir forest is that association which originally covered most of the area above 5,500 feet, but which now, after heavy logging, is found only in a few patches and strips along the summits of the Black Mountains.

The association is a well developed conifer climax. The two dominant species, *Picea rubra* and *Abies fraseri*, usually occur in such dense stands that there is little shrub or herb growth beneath them. The original forest of the slopes contained specimens over 4 feet in diameter, whereas, those along the ridges at high altitudes are small and often sub-alpine growth form. Although pole stands are quite common there are also more open stands forming an association of three strata, the upper dominant tree stratum, the under shrub and young tree stratum, and the forest floor society as a ground stratum. This forest is occasionally

broken by inclusions of herbaceous societies which resemble small alpine meadows and are separate communities, forest inclusion societies.

The Fraser fir is most abundant at high altitudes and the red spruce at low altitudes. In places either may be found in pure stands as consociations. In constancy they both occur in over 80% of the quadrats, in exclusiveness the fir is more confined to this association than the spruce. *Betula lutea*, *Sorbus americana*, and an occasional *Prunus pennsylvanica* occur as codominants in the upper stratum. Both the birch and fire cherry have become locally abundant after logging. The yellow birch becomes more abundant at the lower limits of the formation and is a prominent member of the transition association between the spruce-fir and the northern hardwood forests.

The shrub stratum consists of *Rhododendron catawbiense*, *Viburnum alnifolium*, *Menziesia pilosa*, and *Ribes rotundifolia*. Spruce and fir reproduction is in general abundant. The rhododendron is the most characteristic shrub and locally may form a definite heath society as an understory similar to the one found in the Appalachian forest.

In the forest floor society are many herbs that are typical of boreal forests. Of these, *Oxalis acetosella*, *Clintonia borealis*, *Veratrum viride*, and *Aspidium spinulosum* var. *dilatatum* are the most frequent. The floor is usually covered with mosses and ferns, but in the thicker stands these and the flowering herbs are shaded out. Mosses, liverworts and lichens cover the logs and tree trunks. The *Ptilium* and *Hylocomium* mosses form a veritable mat which is very important in retaining abundant soil moisture. The debris of the forest floor accumulates to form a deep duff and in some places a raw humus or true peaty soil is developed.

FLORISTIC COMPOSITION OF THE SPRUCE-FIR CLIMAX ASSOCIATION

Trees

Picea rubra—F C E
Abies fraseri—F C E
Betula lutea—f C
Sorbus americana—c
Prunus pennsylvanica—L

Shrubs

Rhododendron catawbiense—F c
Viburnum alnifolium—F c e
Menziesia pilosa—f e
Ribes rotundifolia—f e
Acer spicatum—f e
Vaccinium erythrocarpum—f L
Rhododendron maximum—L
Sambucus racemosa—f L
Diervilla sessile—f
Alnus viridis—L
Rubus canadensis—f
Rubus alleghenensis—f
Rubus idaeus var. aculeatissimus—L
Hypericum densifolium
Acer pennsylvanicum

Mosses and Liverworts

Hylocomium prolificum—F C e
Ptilium crispus-castrensis—F C E
Hypnum schreberi—f e
Catharinea undulata—f c
Stereodon curvifolius—f
Thuidium delicatulum—f L
Polytrichum gracile—L
Polytrichum ohioense—L
Dicranum scoparium—L
Dicranella heteromella
Grimmia donnie
Rhodobryum roseum—L
Mnium affine
Mnium punctatum
Sphagnum squarrosum—L E
Sphagnum sp.
Plota crispacrispula
Frullania spp.
Porella platyphylloidea—L

Herbs

Oxalis acetosella—F C E
Clintonia borealis—F c e
Veratrum viride—F C
Streptopus roseus—f c
Aster paniculatus—f c
Solidago glomeratus—F c
Trillium erectum—f c e
Houstonia serpyllifolia—F c L
Saxifraga leucanthemidifolia—F c L
Lilium carolinianum—f
Monarda didyma—f L
Viola canadensis—f c
Aster divaricatus—f c
Chelone lyoni—f L
Impatiens pallida—f
Impatiens biflora—f
Claytonia caroliniana—f L
Trillium undulatum—f E
Smilacina racemosa—f
Melanthium virginicum
Ranunculus abortivus
Lilium grayi
Hypericum punctatum—L
Hypericum ellipticum
Parnassia asariifolia—L
Cuscuta cephalanthi
Allium tricoccum
Agrostis perennans
Carex brunnescens
Juncus biennis

Ferns

Aspidium spinulosum var. dilatatum—F C
Aspidium spinulosum var. intermedium—f L
Aspidium noveboracense—F L
Aspidium felix-femina—f
Polypodium vulgare—f L
Dicksonia punctilobula–f
Aspidium goldianum—f
Lycopodium lucidulum—f e

Secondary successional communities, after logging of the spruce-fir forests

After the heavy logging and, in many places, severe burns, pioneer successional communities have covered the areas once occupied by the conifer climax forest. These communities are very varied, due to differences in age, topography, and condition of the soil. The complex is composed of many associes in different stages of progression toward the original climax conditions. Where the burns have been most severe and erosion has removed most of the soil, there is but little arborescent vegetation, but in the upper coves and on the moist slopes a distinct associes of fire cherry, *Prunus pennsylvanica*, and *Betula lutea* has developed. With them many species of the original forest are associated.

A few young spruce and fir are developing under their shade and some conifers have been planted. As a rule, natural reproduction and replacement of the original forest is too slow to indicate a definite progression back to the climax. However, it seems certain from observations over a ten year period, that these deforested areas will not develop into treeless *balds* or meadows, although Core (3) believes that they do in a similar area in West Virginia.

In the open places, usually on the ridges and drier slopes, brambles of the genus *Rubus* and many herbs form a veritable tangle of vegetation. Some few places have been grazed and are quite bare of all but grasses and herbs. In such small places clovers, grasses and many ruderals are abundant. The most common of the grasses is *Danthonia compressa*. The floristic composition of these devastated areas is very mixed as is shown by the following list.

FLORISTIC COMPOSITION OF THE SECONDARY SUCCESSIONAL COMMUNITIES, AFTER LOGGING OF THE SPRUCE-FIR FOREST

Trees and Shrubs

Betula lutea—F C L
Prunus pennsylvanica—F C e L
Sambucus racemosa—F L c
Rhododendron catawbiense—F L c
Viburnum alnifolium—f L c
Rubus alleghenensis—f c
Menziesia pilosa—f
Diervilla sessile—f
Rubus idaeus var. aculeatissimus—f
Acer spicatum—f
Sorbus americana—f
Hypericum prolificum—f c
Ribes rotundifolia
Alnus viridis
Salix sericea—L
Hydrangea arborescens
Crataegus punctata
Picea rubra
Abies fraseri
Aesculus octandra

Ferns

Aspidium noveboracense—F L c
Aspidium spinulosum var. dilatatum—f c
Dicksonia punctilobula—f c
Woodsia ilvensis
Asplenium filix-foemina—L
Lycopodium lucidulum

Grasses, etc.

Danthonia compressa—F L e
Agrostis perennans—f c
Panicularia melicaria—f
Poa compressa—L
Phleum pratense

Herbs

Eupatorium urticaefolium—F C e
Rudbeckia laciniata—F L e
Thaspium pinnatifidium—F L e
Monarda didyma—f L
Solidago glomeratus—f c
Chelone lyoni—f c
Aster divaricatus—f c
Epilobium angustifolium—f L
Veratrum viride—L
Eupatorium purpureum—f
Monarda fistulosa—L
Pycnanthemum spp.—f
Parnassia asariifolia—L
Achillea millefolia—f
Chrysanthemum leucanthemum

Lactuca canadensis
Oenothera fistulosa
Oenothera biennis
Prenanthes altissima
Senecio aureus
Erigeron racemosa
Cuscuta obtusiflora—L
Convolvulus sepium
Hypericum ellipticum
Hypericum punctatum
Saxifraga leucanthemidifolia—L
Potentilla spp.
Trifolium repens
Rumex acetosella
Fragaria vesca
Ranunculus acris
Melanthium parviflorum
Silene virginica
Vernonia noveboracensis

Transition associations

At the lower limits of the spruce-fir forest are some associations which are transitional between the spruce-fir forest and the northern hardwood forest or in rare cases the Appalachian forest. These montane transition associations are of mixed character containing floristic elements of the forests above and below them. They do not occur in great abundance in the area but as they are a definite ecotone they deserve brief consideration.

The dominant trees are both conifers and hardwoods, and the stands are so mixed and variable that many different associations might be distinguished. For our purpose, only the association where spruce and fir are common will be discussed. This is the usual type.

In this type of association *Picea rubra* is more frequent than *Abies fraseri*. The two dominant and most frequent hardwoods are *Betula lutea* and *Quercus borealis*. These four dominants are in more open stands than in the climax forests and none of the species reach their best development. In more open places, *Aesculus octandra*, and *Crataegus punctata*, are associated with the dominants. Shrubs, as *Ilex verticillata*, *Hamamelis virginiana*, *Rhododendron catawbiense*, *Viburnum alnifolium*, *Acer pennsylvanicum* and *Vaccinium corymbosum*, are common as an understory. The herbs are very similar to those in the spruce-fir forest and indicate similar habitat conditions.

The northern hardwood climax association

It is difficult to fix the limits of this association and to characterize it, for the floristic components are not very exclusive and many of the species are often found mixed with the Appalachian forest complex. It is best developed in the coves and on the moist slopes and not on the ridges and peaks. At the upper limits of its range the same species may spread out on the ridges, but these form open savanna associations or the orchard type.

The dominant and most constant trees are *Acer saccharum, Fagus grandifolia, Aesculus octandra, Tilia heterophylla michauxii, Betula lutea, Fraxinus americana, Prunus serotina,* and locally *Halesia carolina.* These dominant trees often reach large size and the canopy is very dense so that there is little development of an understory of shrubs. The herbaceous flora after the vernal display is sparce.

The chestnut, Canada hemlock, yellow poplar and a few deciduous magnolias invade the association at its lower limits. There are many different species of shrubs and herbs, most of which are typical of the beech-maple climax in the northern states. Ferns are not as frequent as in the spruce-fir forest and mosses are strikingly less abundant.

FLORISTIC COMPOSITION OF THE NORTHERN HARDWOOD CLIMAX ASSOCIATION

Trees

Acer saccharum—F C e
Tilia heterophylla michauxii—F c e
Aesculus octandra—F c e
Fagus grandifolia—f L c
Betula lutea—f c
Quercus borealis—f c
Fraxinus americana—f c L
Tilia sp.—f
Prunus serotina—f c e
Castanea dentata—L
Halesia carolina—R
Ostrya virginiana—f
Acer rubrum—f
Crataegus punctata—f
Tsuga canadensis—L

Shrubs

Viburnum alnifolium
Acer spicatum
Hydrangea arboreum
Hamamelis virginiana
Cornus alternifolia
Vaccinium erythrocarpon
Rhododendron catawbiense
Rhododendron maximum
Viburnum acerifolium
Ilex monticola
Benzoin aestivale
Sambucus racemosa
Vaccinium corymbosum
Smilax hispida
Rubus odorata
Rhus toxicodendron
Aristolochia sipho
Vitis spp.
Amelanchier canadensis
Clematis viorna
Clethra acuminata

Ferns

Phegopteris polypodioides
Polypodium vulgare
Asplenium acrostichoides
Aspidium noveboracense
Aspidium goldianum
Aspidium marginale
Aspidium spinulosum var. dilatatum
Osmunda cinnamomea
Osmunda claytoniana
Osmunda regalis
Botrychium virginianum
Camptosorus rhizophyllus
Lycopodium lucidulum

Herbs

Cimicifuga rubifolia—F c E
Osmorrhiza brevistylis—F C
Hydrophyllum canadensis—F c
Actaea alba—F L E
Hepatica triloba—F L e
Viola rotundifolia—f L e

Campanula americana—f L
Rudbeckia laciniata—f L
Trautvetteria carolinensis—f c
Aquilegia canadensis—f
Dentaria heterophylla—f
Viola canadensis—f e
Impatiens pallida—f L
Impatiens biflora—f L
Geum canadensis—f c
Circaea intermedia—f c
Galium lanceolatum—L
Medeola virginica—L
Geranium maculatum—f
Polypodium peltatum—L
Laportea canadensis—f
Diphylleia cymosa—L
Allium tricoccum—f c
Trillium undulatum
Trillium grandiflorum
Polygonatum biflorum
Polygonatum commutatum
Uvularia sp.
Lilium carolinianum
Lilium grayi
Orchis spectabilis
Habenaria ciliaris
Listera smallii
Cypripedium parviflorum
Viola incognita
Hybanthus concolor
Dioscorea villosa
Caulophyllum thalictroides
Thalictrum caulophylloides
Pogonia verticillata
Pedicularis canadensis
Aconitum reclinatum
Stachys nuttallii
Prunella vulgaris
Monarda didyma
Eupatorium urticaefolium
Solidago spp.
Sanicula trifoliata
Panax quinquefolia
Amphicarpa monoica
Sanguinaria canadensis
Smilax herbacea
Conopholis americana
Epiphagus virginiana
Epipactis repens
Heuchera hispida

The sub-alpine orchard association

This association is limited to the upper slopes and ridges of the northern hardwood formation. The open nature of these stands and their dwarfed and gnarled appearance warranted the apt descriptive name of *orchard,* in common use by the natives of this region. The dominant species, *Fagus grandifolia, Betula lutea, Aesculus octandra,* and *Crataegus punctata,* never reach the full size attained in the climax forest and the development of a sub-alpine form gives a distinct physiognomy to the community. There is little development of undershrubs or natural reproduction of the dominant tree species. This condition is probably due to the abundance of flowering herbs and ferns of the forest floor growing in rank profusion to the height of a man's shoulder.

The open nature of these sub-alpine communities and their occurrence adjacent to the mountain meadows or grassy *balds* suggests the possibility that they may be transition stages between the climax association of this formation and the balds of the mountain tops. The abundance of herbs on the forest floor crowding out and limiting natural reproduc-

tion and replacement of the dominant species indicates the possibility of a retrogression from forest community to herbaceous or shrub communities.

The sub-alpine savannas

Associated with the orchard association but distinct from it are open communities of beech and yellow birch in almost pure stands as consociations. The greater number of grasses on the forest floor of the savannas and the presence of one or at most two dominants distinguishes the two. Otherwise, the floristic composition of the savanna type is much like the orchard association.

The Hypericum savanna association

Another common variant from the northern hardwood climax type is the *Hypericum* savanna. On the drier slopes and ridges at the upper limits of the northern hardwood formation this association occurs usually as a transition between a high Appalachian slope type of forest and a spruce-fir transition association. The distinctive floor society dominated by *Hypericum prolificum* best distinguishes the association.

The balds

In this section the term *bald* is applied by the natives to natural treeless areas throughout the region. The term is borrowed from local usage and is used in this paper to designate those communities in the northern hardwood and spruce-fir forests that are composed of shrub and herb species and not of trees. Harshberger (7) describes them as sub-alpine treeless formations. They might well be considered as separate formations except for the fact that it seems better to consider them as physiographic and edaphic variants from the formations with which they are associated. They are here considered with the northern hardwood complex because the species of shrubs and herbs in them are most commonly associated with this formation. They are in all probability edaphic climaxes as indicated by data on soil acidity obtained by the writer, Davis (4), in this region, and by Cain (2) in the Smoky Mountains. Two types of balds may be distinguished: the grassy *bald* associations and the heath *bald* associations. The grassy *balds* are sub-alpine mountain meadows, the shrub *balds* are called heath associations because ericaceous species predominate. Both intergrade freely and often there is no sharp line of demarcation between the two.

Both grassy and heath balds are most commonly found between 5,000 and 6,100 feet along the high ranges in exposed situations, being best developed in this area along the Craggy Range. On Grandfather Mountains, as described by Harshberger (7) and others, and in the Smoky Mountains as observed by the writer, heath and distinctive *Leiophyllum-Dendrium* associations are found at higher and at lower elevations than those given here, but in this area these openings in the forest exist most commonly at the altitude of the transition zone between the northern hardwood and spruce-fir forests.

The grassy bald association

These open pasture-like bald places along the ridges offer a striking contrast to the forests that approach to their very edge. They are bare of arborescent vegetation, except for a few shrubs, and show no tendency of progression toward a forest type. They may be due to a number of causes, one of which was suggested in outlining the *orchard* association, that is, failure of the orchard association to replace its tree species. Other causes may be grazing, fire, or cutting, but as far as can be determined from the oldest inhabitants of this area they have been as they now are, treeless for a long period of time. There is no legend or evidence of Indian occupancy or of fire. Grazing may have promoted their development but does not seem a cause.

The community is characterized by many grassy plants, other herbs and a few ferns. The mosses and grassy plants and some of the common herbs form a distinct sod spotted with tussock-like patches of different species. A few shrubs, notably *Rhododendron catawbiense,* occur locally in patches in the grassy balds.

The most characteristic of the grassy plants are *Juncus bicornis* in tufts, *Danthonia compressa* in mats, *Poa compressa, Agrostis perennans, Carex intumescens, Phleum pratense* and *Festuca elatior.* With them are associated many ruderals and other herbs that are characteristic of open sub-alpine meadows. Mats of the moss *Polytrichum commune* are locally conspicuous. Only a few ferns are present and lichens are found mostly on the rocks.

The soil is thin in this association and rock outcrops are common. From instrumental data, Davis (4), the soil has been found to be very acid. The plants are subjected to the greatest extremes in atmospheric conditions and in soil temperatures. The association is distinctly a physiographic-edaphic climax.

FLORISTIC COMPOSITION OF THE GRASSY BALD ASSOCIATION

Grasses, etc.

Juncus bicornis—F C L e
Poa compressa—F c e
Agrostis perennans—F e
Poa pratense—f c
Festuca elatior—f
Danthonia compressa—L
Carex rosea radiata—f
Carex tenuis
Carex brunescens
Phleum pratense
Deschampsia flexuosa

Shrubs

Rhododendron catawbiense—F L
Menziesia pilosa—f e c
Vaccinium erythrocarpon—f c
Alnus viridis—f
Diervilla sessile—f
Hypericum prolificum

Mosses

Polytrichum commune—f e
Grimmia donne—f e
Dicranum scoparium
Sphagnum sp.
Dicranella heteromella

Ferns

Aspidium noveboracense—f
Dicksonia punctilobula

Herbs

Potentilla canadensis—F L c
Rumex acetosella—F C e
Trifolium repens—F c e
Veronica officinale—F c
Krigia montana—f L
Oxalis stricta—f c
Chelone lyoni—f c
Ranunculus abortivus—f L
Solidago glomeratus—f c
Rudbeckia laciniata—f L
Prunella vulgaris
Silene virginica
Achillea millefolium
Veronica serpyllifolia
Phlox divaricata
Oenothera fruticosa
Monarda fistulosa
Hypericum ellipticum
Solidago curtisii
Fragaria vesca
Saxifraga leucanthemidifolia
Geum radiatum
Erigeron racemosus
Coreopsis pubescens
Chrysanthemum leucanthemum
Solidago patula

The heath bald association

This ericad shrub community is not as well developed in this area as is the grassy bald association. The association is very similar to the alpine type of scrub known as "krumholz," but the development of this association does not seem to represent the true alpine condition as found on Mount Marcy, New York, by Adams, et al. (1), nor do the shrubs develop the extreme forms described by Forsaith (5), in certain alpine communities of New Hampshire.

The vegetation is made up of a few dwarfed tree species and many shrubs. These shrubs and dwarf trees grow so thickly and so closely interlocked that passage is difficult. The Catawba rhododendron is

the most dominant species and *Pyrus melanocarpa* is the most exclusive. There are small grassy-herbaceous societies in the heath bald and bare rock protrusions are common. The soil is thin and very acid and an upland peat soil is often formed by the accumulation of raw humus. There is extreme exposure to climatic conditions as indicated from instrumental data obtained in the study.

These heath *balds* seem to be encroaching upon the grassy *balds* but there is no indication of a development toward a forest type. Neither fire nor cutover seems to explain their presence. They are best considered as physiographic-edaphic climaxes.

FLORISTIC COMPOSITION OF THE HEATH BALD ASSOCIATION

Shrubs and trees

Rhododendron catawbiense—F c L
Menziesia pilosa—f c
Kalmia latifolia—f
Vaccinium erythrocarpon—f e
Pyrus melanocarpa—f E
Vaccinium corymbosum—f
Alnus viridis—f
Ribes rotundifolia
Azalea canescens—f e
Viburnum alnifolium
Acer spicatum
Betula lutea
Fagus grandifolia
Prunus pennsylvanica
Crataegus punctata
Ilex verticillata
Diervilla sessile
Vaccinium neglectum—E

Herbs

Maianthemum canadensis—f c e
Oxalis acetosella—f c
Clintonia borealis—f c
Mcnotropa uniflora—f e
Trillium spp.
Streptopus roseus
Veratrum viride
and others common to the spruce-fir forest

Ferns

Aspidium spinulosum var. dilatatum—f
Aspidium filix-foemina—f L
Osmunda cinnamomea—f e
Lycopodium lucidulum—f c

The Appalachian Forest Formation

The minor communities of this complex are much more varied than the communities of the two higher formations. A number of climax associations may be distinguished and, although they may be made up of very similar floristic elements, no one climax is quite like the other. The Society of American Foresters (12) classifies five major forest types in the Appalachian complex. Most of the climax types are confined to the lower or protected slopes and valleys or coves of this area. Few original stands remain uncut. There is a general cove hardwood climax type with *Tsuga canadensis* associated. The other climax types may be considered as variants from this general type.

The cove climax association

This is the richest and was originally a very extensive forest in the region. It is made up of a great number of southern hardwood species that reach large size and form a tall forest with a heavy canopy. The best development of this association is at middle altitudes between 2,500 and 3,500 feet; but it may be found in rich coves as far down as the piedmont and at higher altitudes almost to the spruce-fir forest. The high coves, locally called flats and benches, are somewhat distinct and are discussed here as the high cove association. In some places where beech and hemlock are abundantly dominant a distinct hemlock-beech association is found. This latter is probably the highest development of mesic forests in the area.

It is difficult to give the constant tree dominants of this generalized cove association, but in over 85% of the quadrants studied, *Castanea dentata*, *Liriodendron tulipifera*, *Tsuga canadensis*, *Quercus borealis* and *Acer rubrum* are the most frequent. Other species less frequent generally are locally abundant. Over 40 species of trees are common to this association, although only about two thirds of this number may be found in any one cove area. This great diversity of tree species is a most characteristic feature of the Appalachian forest. Some of the trees, as *Platanus occidentalis*, *Betula nigra*, and *Carpinus caroliniana*, have invaded the cove areas from the piedmont along the water courses. Other species, as the buckeye and yellow birch, are more typical of higher altitudes. Some trees, as the beech and northern red oak are about as constant here as in the northern hardwood forest.

The very typical evergreen shrub society of *Rhododendron* and *Kalmia*, with locally abundant *Leucothoe catesbaei*, associated with other shrubs is so definite and distinct that it is treated as a separate community. This abundance of heath shrubs as an understory society in the cove association is a most characteristic feature of this community.

The herbaceous society of the forest floor is very variable in species, depending to a large extent upon the nature of the dominants and the density of the shrub stratum. Under the hemlocks and rhododendrons there is a paucity of herbs but in more open stands herbs may be abundant. Ferns are locally very abundant, and mosses, ferns, liverworts and fungi cover the rocks, soil, and decaying logs. All climatic measurements made indicate very mesic conditions. The forest may be considered the climatic climax development of the southeast.

The cove hemlock-beech association

In some of the richer coves these two species form a distinct association. The Canada hemlock or the beech may occur locally in almost pure stands forming a consociation in the general complex, but the two are usually associated together. From descriptions of old inhabitants, and from the examination of similar forests in adjacent regions, this forest may be considered as being at one time very extensive along the moist stream bottoms. The hemlock is still the most characteristic tree of the stream borders. With the beech and hemlock the yellow poplar was commonly associated and the chestnut was locally a dominant member. Now little of this rich cove forest remains.

This association, especially where the hemlock is predominant, lacks a definite shrub stratum. The herbaceous floor society is also poorly developed, but such species as *Mitchella repens, Epipactis repens, Houstonia nummularia, Galax aphylla, Viola rotundifolia* and *Listera smallii* are most characteristic. The soil is often a raw humus and has proved to be very acid.

The high cove association

This association is locally known as a "spruce flat" or "bench" and it usually occurs as a transition type between the true Appalachian cove climax and the northern hardwood climax. It is best distinguished from the northern hardwood association by the dominance of hemlock and by the presence of such Appalachian species as *Castanea, Liriodendron, Juglans* and *Rhododendron maximum* associated with the common northern hardwood dominants.

The Rhododendron-Kalmia shrub society

The two most typical and frequent shrubs of the Appalachian forest are *Rhododendron maximum* and *Kalmia latifolia*. They are associated with many other shrubs and occur commonly in the cove forest associations and on the cooler and damper mesic slopes. The *Rhododendron* is more abundant than the *Kalmia* in the climax forests, while the *Kalmia* is more abundant on the mesic and xeric slopes. Where best developed along the streams the two heaths are associated in dense stands and may reach a size of 10 inches in diameter. They give a distinct aspect to the forest, especially in winter when the deciduous species are bare. Although these broad sclerophylls may be found in many habitats they best develop where the soil is markedly acid. In this respect this society resembles the other heath communities of the area.

The intense perennial shade formed by these shrubs excludes most plants from the forest floor. Seedlings of *Tsuga, Aesculus, Fagus* and *Acer* are sparingly found. A few herbs, notably *Mitchella repens, Epipactis repens, Viola rotundifolia, Uvularia perfoliata,* and the *Osmunda* ferns make up the floor society.

This heath society is not limited to the rich coves and moist slopes but may be found locally abundant throughout the Appalachian formation. *Kalmia* in pure stands is a marked feature of some of the more open and drier slopes.

The mesic slope association

The moist intermediate slopes of the Appalachian formation support the most extensive forest of the area. The best stands of commercial timber are produced here and the greatest amount of lumbering has been done on these slopes. The communities of these slopes are highly mesophytic. It is often difficult to distinguish this type from the cove climax. The association intergrades usually at its upper limits with the xeric slopes and ridge association which contains pines and dry situation oaks.

Castanea dentata and many mountain oaks associated with it are the most characteristic floristic feature of the mesic slopes. The prevalence of oaks and the paucity of hemlocks and pines set off this community as distinct. The association is composed of a great number of southern hardwoods as dominants, of which *Castanea dentata, Quercus alba, Q. montana, Q. velutina, Q. coccinea, Q. borealis, Nyssa sylvatica, Oxydendron arboreum, Robinia pseudacacia,* and *Carya alba* are the most frequent tree species.

The trees do not develop to as large a size as they do in the coves and the lateral spacing is much wider. A shrub stratum is present. The characteristic *Rhododendron-Kalmia* society of the coves is locally found. Herbs are even more abundant than in the coves and the mosses, and fungi are less abundant.

Many variations from the general type described have been observed. The white oak, chestnut, and yellow poplar are often found in consociations of local extent. The chestnut type and the chestnut in mixed types are slowly disappearing through the death of the species from chestnut blight.

The mesic slope association is very rich in number and variety of species and many of these are the most characteristic of the Southern Appalachian flora.

The xeric slope and ridge association

These communities are limited to dry slopes and ridges, but some of the species are pioneers in the successional communities on cutover and cleared areas throughout the Appalachian zone. These associations are characterized by the predominance of pines and dry situation oaks. The mountain pines, *Pinus rigida, P. pungens,* and at lower elevation piedmont pines, *P. virginiana* and even *P. echinata,* are dominant members of the association. Associated with them are *Castanea dentata, Quercus montana, Nyssa sylvatica, Quercus coccinea,* and *Oxydendron arboreum.* The hardwoods are stunted and poorly developed and do not occur as constantly as do the pines. The pines are often in pure stands as consociations, which resemble the lowland flatwoods in many characters of the flora and the acid nature of the soil. The trees are in open stands and never reach large size. A savanna type is common.

The shrubs that form a prominent understratum are most typical and exclusive. Of these, *Myrica asplenifolia, Castanea pumila, Amorpha canescens, Robinia hispida, Gaylussacia resinosa,* and *Vaccinium vacillans* are frequent and give character to the association. In certain places *Kalmia* grows locally in such abundance as to form a *Kalmia* consociation.

The herbs, as may be noted from the list, are also exclusive. In fact, the flora of this association is very distinctive. It resembles the pine barrens throughout the east. Adjoining the piedmont and plateau formations the pine associations of these xeric situations include *Pinus echinata* and *P. strobus.* The presence of heaths, particularly *Vaccinium* and *Gaylussacia* is one point of similarity between these pine communities and the pinelands of the coastal plain.

Floristic composition

The floristic composition of the three principal associations of the Appalachian forest formation are so mixed that one list gives a better estimate of the species than separate lists and also furnishes a more adequate means of comparison. The flora of each association may be distinguished by means of the symbols of frequency, occurrence and exclusiveness. The species are arranged in approximate order of their importance in each association, but all the most abundant in the cove climax are listed before the mesic slope, and these two before the xeric slope and ridge association. Only the most abundant and significant herbs are given.

FLORISTIC COMPOSITION OF THE APPALACHIAN FOREST FORMATION

	CLIMAX COVE ASSOCIATION	MESIC SLOPE ASSOCIATION	XERIC SLOPE AND RIDGE ASSOCIATION
Trees			
Castanea dentata	f c e	F C e	f c
Liriodendron tulipifera	F C E	f L	
Tsuga canadensis	F c E	p	
Acer rubrum	F c	f	f
Quercus borealis	F c	f c	
Magnolia fraseri	f c E	L	
Tilia heterophylla	f c	f	
Fraxinus americana	f L e	p	
Betula lutea	f L		
Betula lenta	f c e	f L	f
Juglans nigra	f c e		
Magnolia acuminata	f L E		
Nyssa sylvatica	f	F c e	f
Quercus alba	f	F L e	f
Quercus montana	f	F C e	
Acer saccharum	f L e	f	
Aesculus octandra	L e		
Juglans cinerea	L E		
Platanus occidentalis	L e	f	
Hicoria ovata	f	p	
Hicoria alba		f c e	f
Oxydendron arboreum		f c	F C
Quercus velutina	f c e		
Carpinus caroliniana	L E		
Robinia pseudacacia		F	f
Salix nigra	L E		
Quercus coccinea		f	F C e
Hicoria pallida		f c e	f
Hicoria glabra	p	f	
Prunus serotina	p		
Sassafras variifolium		F c e	f
Ilex opaca	L		
Halesia carolina	L	f	
Diospyros virginiana	p	f	
Pinus strobus	L e		
Ilex monticola		f	
Viburnum lentago	p e	f	
Fraxinus biltmoreana	p e		
Amelanchier canadensis	p	f c e	f
Ostrya caroliniana		f	
Quercus stellata		L	f L e
Pinus pungens		f	F C E

	CLIMAX COVE ASSOCIATION	MESIC SLOPE ASSOCIATION	XERIC SLOPE AND RIDGE ASSOCIATION
Trees—Concluded			
Pinus rigida		f	F C E
Hicoria cordiformis		p	f e
Tsuga caroliniana			L E
Shrubs and vines			
Rhododendron maximum	F L c e	f L	
Kalmia latifolia	F c e	F c	f L
Hamamelis virginiana	F c	f c e	p
Viburnum acerifolium	F c	f c e	
Benzoin aestivale	f c e	f c	
Clethra acuminata	F E	f	
Symplocos tinctoria	F c	f c	
Hydrangea arborescens	f c	F c e	
Smilax rotundifolia	f c	f c	
Smilax hispida	f	f	f
Calycanthus fertilis	L E		
Acer pennsylvanicum	f	f c	
Cornus florida	f	F c e	
Aralia racemosa	f L e	f	
Salix sericea	L E		
Azalea arborescens	L E		
Amorpha fruticosa	f	f c e	
Viburnum dentatum	p	L	
Rhus hirta	p	L	
Vaccinium stamineum	f	F c e	
Vaccinium corymbosum		f	
Rhus toxicodendron	L	f e	
Psedera cinquefolia	p	f	
Rubus strigosus	p	f e	
Alnus rugosa	L E		
Chionanthus virginica	L E	L	
Xanthorrhiza radicans	L e		
Pyrularia pubera	f E	f	
Vitis aestivale	f L	f	
Vitis sp.	f		
Aristolochia sipho	f L	f	
Azalea lutea		f e	F C e
Vaccinium vacillans			F c L e
Leucothoe recurva		F c	f c
Lyonia ligustrina		f	f c e
Pieris floribunda		f	f L E
Hypericum densiflorum		f e	f
Gaultheria procumbens		f L	F c L e

	CLIMAX COVE ASSOCIATION	MESIC SLOPE ASSOCIATION	XERIC SLOPE AND RIDGE ASSOCIATION
Shrubs and vines—Concluded			
Epigaea repens		f	
Amorpha canescens		f	F
Myrica asplenifolia			F C E
Castanea pumila			F C E
Gaylussacia resinosa		f	F L E
Vaccinium pallidum			f E
Ceanothus americanus		f L	F c e
Robinia viscosa		f	F c E
Vaccinium neglectum			R
Alnus crispus			L E
Herbs			
Galax aphylla	f	F C e	f c L
Epipactis repens	f L E	f	
Mitchella repens	f L E		
Clintonia umbellata	f c E		
Smilacina racemosa	f c	f	
Polygonatum biflorum	f c e	f c	
Habenaria psycodes	f c E	f	
Tradescantia virginica	f	f c	f
Mitella diphylla	L E		
Heuchera pubescens	L	f L e	f
Cimicifuga racemosa	f c	F C e	
Osmorrhiza brevistylis	f	f c e	
Laportea canadensis	f L e	f c	
Podophyllum peltatum	f	f c e	
Geranium maculatum	f	f c	
Impatiens biflora	F c	f L	
Houstonia purpurea	f	F C e	f
Hydrophyllum canadense	f	f c	
Thalictrum caulophylloides	f	f L	
Sanguinaria canadensis	f L e	f c e	
Actaea alba	p	f c	
Lysimachia quadrifolia	p	F C e	f
Gillenia trifoliata	f	F c e	f
Aruncus sylvestris	p	f L	
Helianthus laevigatus	p	f c E	
Coreopsis major	f	F c e	f
Gerardia laevigata	p	f c	
Chamaecrista nictitans	f	F c	
Meibomia bracteosa		f	f
Lysimachia nummularia	L E		
Baptisia tinctoria		f c e	f c

	CLIMAX COVE ASSOCIATION	MESIC SLOPE ASSOCIATION	XERIC SLOPE AND RIDGE ASSOCIATION
Herbs—Continued			
Pedicularis canadensis		f c	f c
Scutellaria pilosa		F c	f c
Solidago monticola		f c	
Aster cordifolius		f c	
Silene virginica		F c e	f
Astilbe biternata		f L	
Euphorbia corollata		F c e	f
Dioscorea villosa	f	f c	
Campanula divaricata	f	f	
Hepatica triloba	L	f	
Viola rotundifolia	p	f	
Viola patens	f	f	
Medeola virginica	f	F L	
Monarda fistulosa		f c e	f c
Astragalis canadensis		f	
Asclepias exaltata		f	
Collinsia canadensis	f L	f	
Pentstemon hirsuta		f c	p
Solidago bicolor		f c	p
Cacalia atriplicifolia	f	f c	
Prenanthes altissima		f	
Hieracium venosum		f	f
Commelina virginica	f	f	
Melanthium parviflorum	f		
Uvularia perfoliata	f	f	
Lilium carolinianum	L	f	
Polygonatum commutatum		f L	
Trillium umbellatum	L		
Trillium grandiflorum		f	
Cypripedium acaulis	L	L	
Orchis spectabilis		f c	
Habenaria fimbriata		f	
Pogonia ophioglossoides	f	f	
Pogonia verticillata		f	
Spiranthes beckii		f	
Oenothera fruticosa		f	f
Gentiana andrewsii		f	
Castilleja coccinea		f	
Lobelia cardinalis	L		
Lobelia syphilitica	L		
Potentilla canadensis		f	F c e
Veronica officinalis		f	f c e
Rumex acetosella		f	f c e

	CLIMAX COVE ASSOCIATION	MESIC SLOPE ASSOCIATION	XERIC SLOPE AND RIDGE ASSOCIATION
Herbs—Concluded			
Danthonia compressa			F L e
Helianthus atrorubens			f e
Solidago caesia			f e
Angelica curtisii			f
Habenaria ciliaris			f E
Pycnanthemum quadrifolia			f
Gentianella quinquefolia			f e
Andropogon argyraeus		f	f
Agrostis perennans		f	f
Juncus effusus		f	f
Hypericum gentianoides		f	f
Ferns			
Adiantum pedatum	F L E		
Polystichum acrostichoides	f c	F c e	
Osmunda cinnamomea	f L e	f L	
Osmunda claytoniana	L	f	
Osmunda regalis		L	
Aspidium marginale	f c e	f c	
Aspidium noveboracense	F c	F C	f
Aspidium filix-mas	e	f	
Aspidium goldianum	f	f	
Asplenium acrostichoides	f e	f	
Asplenium ebenoides		L	
Asplenium parvulum		L	
Polypodium vulgare	L	L	
Camptosorus rhizophyllus	L E		
Phegopteris polypodioides		f c e	
Botrychium virginianum		f e	
Pteris aquilina		f	F L E
Dicksonia punctilobula		f	f
Mosses			
Thuidium delicatulum	F C e	F c	
Stereodon curvifolius	F C e	f c	
Leucobryum glaucum	F L	f c	f
Mnium affine	F c	f c	
Catharinia undulata	f c	f L	
Brachythecium sp.	L E		
Dicranella heteromella	f	f c	f
Dicranum scoparium	f	f	
Polytrichum commune		f c	f L
Pogonatum sp.		f L	
Chrysohypnum chrysophyllum	L		

THE PIEDMONT AND PLATEAU FORMATIONS

Below the Appalachian forest occur the piedmont and plateau forest types. They extend up into the mountains along the broad valleys and streams and the flora of the two integrade with the lower Appalachian communities.

The plateau type is found over the Asheville basin and on some of the plateaus or broad valleys to the east and south. It occurs generally between 1,000 and 2,500 feet. Most of these areas have been cleared and few original stands remain. The formation is a mixture of oaks and pines and many different types of associations may be distinguished. It is a transition forest between the mountain Appalachian forest and the piedmont proper. The presence of the southern red oak, *Quercus rubra*, the sweet gum, *Liquidambar*, the river birch, *Betula nigra*, and the Virginia scrub pine, *Pinus virginiana*, easily distinguishes this type from the mountain Appalachian forest. Topography markedly influences the distribution of associations. On the dry ridges and slopes pines and dry situation oaks predominate, whereas on richer soil and more mesic situations the white oak and white pine dominate. There is a distinct riveredge hardwood association composed of such species as *Celtis occidentalis*, *Betula nigra*, *Platanus occidentalis*, *Salix nigra*, etc.

The piedmont formation is much like the plateau except that here *Pinus echinata* is the dominant pine and piedmont hardwoods become more abundant. The lower limits of the Appalachian forest merge imperceptibly with the upper piedmont forest. Certain species, as *Nyssa sylvatica*, *Quercus alba* and *Hicoria alba* are quite as common to one as to the other and even *Kalmia* and *Castanea* may be found far out on the piedmont hills on rich soil and moist slopes.

Neither of these lower-altitude forests are a part of this study but they have been briefly considered for they enter the region in the Asheville basin and along the valleys of rivers that have their headwaters in this area.

Comparison of the climax associations of the three formations

The three forest climax associations outlined as the dominant forests of their respective formations are all very similar ecologically. Each is a true climatic climax forest developed under highly mesic conditions, but their floristic composition is quite different. When species are considered, a sharp comparison can be drawn between the three. For this purpose the following list was prepared. The most exclusive and typical species are used because a better distinction can be drawn. The trees are, however, the dominant species and show plainly the differences in type of forest.

FLORISTIC COMPARISON OF THE THREE CLIMAXES

SPRUCE-FIR FOREST	NORTHERN HARDWOOD FOREST	APPALACHIAN COVE FOREST
Trees	*Trees*	*Trees*
Picea rubra	Acer saccharum	Castanea dentata
Abies fraseri	Fagus grandifolia	Liriodendron tulipifera
Betula lutea	Aesculus octandra	Tsuga canadensis
Prunus pennsylvanica	Crataegus punctata	Acer rubrum
Sorbus americana	Tilia michauxii	Quercus borealis
	Betula lutea	Magnolia acuminata
	Prunus serotina	Magnolia fraseri
	Quercus borealis	Fraxinus americana
	Fraxinus americana	Quercus alba
		Betula lenta
		Juglans nigra
		Fagus grandifolia
		Hicoria alba
		Quercus montana
Shrubs	*Shrubs*	*Shrubs*
Rhododendron catawbiense	Acer spicatum	Rhododendron maximum
Viburnum alnifolium	Hydrangea arborescens	Kalmia latifolia
Menziesia pilosa	Viburnum alnifolium	Hamamelis virginiana
Vaccinium erythrocarpon	Rhododendron catawbiense	Viburnum acerifolium
Sambucus racemosa	Hamamelis virginiana	Clethra acuminata
	Cornus alternifolia	Hydrangea arborescens
	Viburnum acerifolium	Smilax rotundifolia
	Acer pennsylvanicum	Benzoin aestivale
	Rhododendron maximum	Symplocus tinctoria
	Ilex verticillata	Leucothoe catesbaei
		Vitis spp.
		Calycanthus fertilis
		Cornus florida
		Rhus toxicodendron
Herbs	*Herbs*	*Herbs*
Oxalis acetosella	Cimicifuga rubifolia	Clintonia umbellata
Clintonia borealis	Hydrophyllum canadensis	Polygonatum biflorum
Streptopus roseus	Eupatorium urticaefolium	Habenaria psycodes
Solidago glomeratus	Rudbeckia laciniata	Galax aphylla
Veratrum viride	Actaea alba	Cimicifuga racemosa
Aster paniculatus	Geum canadensis	Lysimachia quadrifolia
Saxifraga leucanthemidifolia	Impatiens biflora	Houstonia purpurea
Houstonia serpyllifolia	Viola canadensis	Epipactis repens
Chelone lyoni	Trillium undulatum	Baptisia tinctoria
Aspidium spinulosum var. dilatatum	Phegopteris polypodioides	Gillenia trifoliata
Asplenium filix-foemina	Aspidium goldianum	Dioscorea villosa
	Aspidium noveboracense	Adiantum pedatum
		Polystichum acrostichoides
		Osmunda spp.
		Aspidium marginale
		Botrychium virginianum

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PLATE 30

POLE STAND OF RED SPRUCE NEAR HOPKINS MINE, ON CHEAT MOUNTAIN, WEST VIRGINIA, BEING CUT FOR MINE TIMBERS

Courtesy U. S. Forest Service

THE
JOHN CRERAR
LIBRARY

PLATE 31

CLINTONIA BOREALIS RAF. BOREAL HERB TYPICAL OF SPRUCE-FIR FOREST

THE
JOHN CRERAR
LIBRARY

A TAXONOMIC AND MORPHOLOGICAL STUDY OF SOME MEMBERS OF THE SAPROLEGNIACEAE

By James Vernon Harvey

Plates 32 and 33

Introduction and Historical

Adametz (1886), the first investigator to study the soil fungi from a scientific point of view, isolated within a period of four years eleven forms of fungous life, mainly *Mucor*, *Penicillium* and *Aspergillus* species. Samples were taken at the surface and at depths of 25–30 centimeters from sandy and loamy soils. He reached the conclusion that both kinds of soils harbored the same species. Adametz, and later, Reinitzer (1900), Nikitinsky (1902), and others studied fungous flora from the soils, mainly ascomycetes and zygomycetes, for the purpose of analyzing their biochemical activities.

Oudemans and Koning (1902) made a study of the soil fungi, giving a classification of the organisms found and full descriptions of the same. Butler (1907) isolated several species of *Pythium* from the soil. Hagem (1907, 1910), in Norway, studied soils from meadow, garden, forest, etc., for their content of Mucorales. Hagem found also such forms as *Penicillium* and *Aspergillus*. Lendner (1908) isolated a number of Mucors from the soils in Switzerland. Dale (1912), in England, obtained fungi from the soils, *Mucor* and ascomycetous forms. Duggar (1911) has carried on researches to determine nitrogen fixation in certain forms, mainly among the basidiomycetes found in the soil.

Goddard (1913) secured many of the same species as were found by Dale, paying especial attention to nitrogen fixation. Waksman (1916) has identified many Mucors and ascomycetous forms, as well as Bacteria, taken from garden, orchard, and meadow soils; these plants were studied from the standpoint of their soil activities. Bristol (1920) has discovered and isolated many of the common green and blue-green algae from desiccated English soils.

Before the appearance of the writer's first paper (1925), except for two species of *Aphanomyces* parasitic on the roots of garden peas (Jones and Dreschler, 1925, and Peters, 1911), no one, as far as the writer has

been able to find, has made mention of the isolation of the true watermolds from the soil. As brought out in this paper (1925), it was found that in nearly all soils many of the common watermolds were contained to a depth of six inches or more. In addition to the established species found, many rare or new forms were obtained.

There were isolated two new species of established genera, *Pythiopsis intermedia* and *Leptolegnia subterranea*. There occurred also two new species of an interesting new genus, *Geolegnia inflata* and *Geolegnia septisporangia*. One member of the Blastocladiaceae, *Allomyces arbuscula*, was isolated a few times. *Pythium deBaryanum* and *Pythium monospermum* were abundant, while no other identified Pythiaceae were secured.

The next paper published was that of Coker and Braxton (1926), the result of continued researches at the University of North Carolina. Many species of watermolds, both old and new, from the soils of North Carolina and South Carolina, were added to the list begun by the author (1925).

Further work was carried out at Chapel Hill by Dr. Coker and by the staff of the Department of Botany of the University, which resulted in the isolation of many forms of the Saprolegniaceae. At the same time Dr. J. N. Couch (1927) secured many species from the soils around Cold Spring Harbor, N. Y. The writer worked during the summer of 1926 at Madison, Wisconsin, obtaining water fungi from the soil.

As a result of the combined studies of the persons mentioned above, there was established a second new genus of the Saprolegniaceous flora, *Brevilegnia* (Coker and Couch). New species were contributed to this new genus by Dr. Coker, Dr. Couch, and the writer.

During the school year of 1926–27 the author continued researches on the soils of Oklahoma and secured many of the forms previously taken. During the summer of 1927 the writer worked again at Madison, using soils collected during the preceding spring in Mississippi; the list of soil watermolds was further extended. Also during the summer of 1927 a number of soil samples were secured by the writer from Lockport, N. Y., researches being made upon these during the autumn. A new species of *Brevilegnia* was isolated, which will be described in full elsewhere in this paper.

While in teaching residence at Richmond, Ky., during the spring, 1928, a number of soil samples were taken by the writer. These, plus a few samples secured from Tuxedo, N. Y., have been the subject of attention up to the time of the writing of this paper, especially during the summer of 1928. Interesting results have been obtained therefrom.

In the present paper there is given a brief account of results obtained after four years of study on the aquatic fungi found in the soils of North Carolina, Wisconsin, Oklahoma, Mississippi, New York, and Kentucky, from which states a total of 775 samples have been secured.

Methods of collection and culture have been described in full previously (1925). Nothing new need be added except to say that, at first, in order to get collections as free as possible from outside contamination, sterile collecting bottles of 100 cc. size were used in collecting. However, it was found later that ordinary commercial envelopes would suffice, there being little or no contamination; the last 275 collections were taken in envelopes.

COLLECTION DATA AND DESCRIPTION OF A NEW SPECIES

It is strikingly noticeable that only one species of *Saprolegnia*, *S. ferax*, has occurred in any of the 775 collections. *Achlya caroliniana* has been found only once outside of North Carolina, while *A. flagellata* has been abundant over all the territory from which samples of earth have been taken. *Achlya hypogyna* and *A. racemosa* were isolated once each at Chapel Hill, these being found in no other collections. *Isoachlya eccentrica*, reported once previously (from the type station, 1923), was secured five times from the soils at Chapel Hill, but this form has not been taken since. A new species of *Pythiopsis* and a new species of *Leptolegnia* (both mentioned previously) were secured several times at Chapel Hill and, later, elsewhere. Non-fruiting cultures of *Dictyuchus* were taken twice at Chapel Hill and a number of times from Wisconsin, Oklahoma, and Mississippi. *Dictyuchus Magnusii*, a rare form, has been found in Mississippi (once only). *Aphanomyces stellatus* and *A. laevis* have been isolated from North Carolina soils, once and three times respectively; an unidentified species, probably of *Aphanomyces*, has been taken from Wisconsin. *Allomyces arbuscula* occurred twice at Chapel Hill and was found to be abundant in Mississippi and Kentucky soils; also this species has occurred in Wisconsin and Oklahoma. *Pythium deBaryanum* and *P. monospermum* have been plentifully obtained, the latter mostly at Chapel Hill.

Ascomycetous and zygomycetous forms have been common, but no attempt has been made to identify them. The Mucors, Aspergilli, and Penicillia were most abundant.

Beginning with the description of a new species of *Brevilegnia* from New York State, the following pages give briefly an account of the entire 775 collections. The last 575 collections were made between June 9,

1926, and June 10, 1928, from the states previously named, excepting North Carolina, where the initial 200 collections were made.

Brevilegnia megasperma n.sp.

Mycelium in mature cultures very dense and opaque, prominently white, usually reaching a ring growth of 15 mm. within three weeks on hemp seed, sometimes greater, often less, the mycelium seemingly at times slightly shrunken, a few hyphae distinguishable at the outer edges. Hyphae slender, sparingly branched, practically the same width throughout; 8.3–25μ broad, mostly 12–13μ. Primary sporangia terminal on main hyphae, not much broader than the hyphae, often slightly swollen toward the outer end, rarely pronounced club-shaped; 91.7–235μ long, 18.3–25μ broad. Secondary sporangia similar to primary, formed at the tips of hyphal branches which arise by lateral proliferation from immediately below the primary sporangia. Spores usually about 11.7μ broad, rounded or slightly angular when compressed within the sporangium; formed in a single row, or rarely in more than three rows, varying with the thickness of the sporangia or of parts of the same sporangium. Spores encyst within the sporangium and escape after decay of the sporangial wall by floating away or very often by the spore protoplasts escaping by amoeboid movement, these assuming a reniform shape and acquiring two laterally placed cilia; the spores very often sprout in place, the delicate hyphae ramifying through the entire mycelium, adding to the opaqueness of the mycelium. Gemmae plentiful in some cultures after a few days, dark and very dense, rarely with a central clearer region; seldom varying from 50–60μ in length and 25–36μ in breadth; may give rise to sporangia, but more often sprout into hyphal filaments, which add to the density of the mycelial mat. Oogonia strikingly abundant, very often in compact masses; spherical, occasionally elongate or ovate to obovate, seldom with one or more papillae; borne for the most part at the tips of lateral branches arising from the main hyphae, though occasionally terminating the main hyphae, seldom intercalary; when on lateral branches there may be as many as five or six oogonia in a cluster, or other oogonia may arise at the tips of secondary lateral branches, which may be long and coiled; 30–55μ, mostly 31.7–35μ, in diameter. Oogonial wall about 1.5μ thick. Oogonial stalks up to 115μ long, being usually not over 7μ broad. Oospores, constantly one to each oogonium, large but not filling the oogonium, spherical; eccentric, possessing a large lateral oil drop; oospore protoplasm finely granular, continuous or discontinuous on the outer side of the oil globule; 21.6–33.3μ broad, mostly 25–26.6μ. The oil drop may reach the diameter of 20μ. The oospore wall usually about 1.3μ thick. Antheridia conspicuously absent, but sometimes present and then hypogynous; empty antheridia seldom noticed.

The plant was first found September 3, 1927, near Lockport, N. Y., on the farm of J. A. Stall, taken from a depth of two inches in wet loamy soil from around the roots of *Prunella* and grass in open woods; taken

again May 12, 1928, from a ravine near the L. & N. R. R. right-of-way, about one mile north of Richmond, Ky., this time from a depth of seven inches in moist crumbly loam (limestone area) underneath a young elm; also isolated from damp loamy soil, removed from a roadside ditchbank, north of the country club near Richmond, soil being taken from around the roots of grass and from around moss.

The prominently white mycelial mat owes its density to the interlacing secondary hyphae, the abundance of oogonia, the sprouting gemmae and sprouting spores within the sporangia, the delicate hyphae (germ-tubes) of the spores intermingling with the other hyphae.

On one occasion, when a microscopic slide containing a mass of mycelial threads and sporangia was left overnight in a damp chamber, the spores in the sporangia nearest the edge of the slide (and just underneath the cover glass edge) sprouted in place and gave rise to delicate, long hyphae, which formed at their tips, farther inward, secondary sporangia.

In younger generations, a culture may show after about three weeks renewed growth, the peripheral region of the culture extending in ring growth about five millimeters and exhibiting a fairly delicate and clear appearance, which may after a few days become dense, then being undifferentiated from the remainder of the mycelium.

The new plant differs from *Brevilegnia diclina* (Harvey, 1927) in that the oogonia are much larger and typically spherical, seldom with papillae or projections. The oogonia of *Brevilegnia diclina* are seldom over 25μ in diameter, while those of the new form are never under 30μ in diameter. Also spore dispersal is different, in that the spores of the present form are very often normally amoeboid in their behavior, as in *Dictyuchus*, the protoplast of a spore emerging gracefully and becoming, after emergence, at first rounded, and then kidney-shaped, acquiring two laterally placed cilia. After some time, fifteen or twenty minutes, the spore may swim slowly away.

The new plant does not resemble *Brevilegnia unisperma* or any of its varieties, except variety *delica*. The new form, to a certain extent, agrees with *B. unisperma* var. *delica* (Coker, 1927) in the shape of the sporangia and in spore activity. The oogonia and oospores[1] are, however, much larger than those of variety *delica*. The size of the oogonia in all forms of *B. unisperma* is below that of the new species under discussion.

[1] The term "oospore" is used here instead of such words as "egg" or "ripened egg," as heretofore used by the writer and as used now by other writers. Probably the word "oospore" is more correct.

The new plant agrees in no way with *Brevilegnia bispora* (Couch, 1927) or with *B. subclavata* (Couch, 1927) in reference to sexual reproductive habits. There is likewise very little resemblance in sporangial characters.

Apparently frequent changes of water, at least as often as once in two days, halt the development of oogonia. Cultures made October 17, 1927, and kept supplied with fresh water (distilled and autoclaved), had degenerating oogonia, when observed again on November 9, 1927; when set aside on the last date and observed again November 15th, abundant material with maturing oospores was noted.

Material placed in a bottle of water and tightly stoppered on January 24, 1928, was readily recultured on July 5th, when the bottle was opened. The plant in the renewed cultures appeared as hardy and healthy as those recently begun from fresh soil. Cultures dried out in petri dishes and covered with dry, sterilized sand, showed rapid growth when carried through the usual culture methods seven months later. The new species is possibly the hardiest that the experimenter has isolated thus far, even though other plants have at the same time shown wonderful reviving qualities.

The new plant grows well on corn meal agar, hyphae being "clean cut" and observable to the naked eye. Sporangia are abundant after a few days, spores for the most part often sprouting in place. When grown on nutrient agar, the plant produces a coarsely branched mycelium, with few sporangia and no oogonia. The plant grows well on pumpkin agar, producing abundant sporangia, but no oogonia. All cultures have been grown from single spore "stock" cultures.

Brevilegnia diclina. Since the first isolation of this species it has been found very commonly in the soils of Oklahoma, Mississipi, New York, and Kentucky. The habitat is very similar to that of *Geolegnia inflata* and *G. septisporangia* (see below). The species has been taken 53 times in 575 collections.

Geolegnia inflata. Since the discovery of this species, when it was taken three times in 200 soil samples (1925), the plant has been found to be fairly common in certain localities, especially in the vicinity of Madison, Wisconsin. At Madison this species was taken 37 times in 200 collections and later 28 times elsewhere, over Oklahoma, Mississippi, New York, and Kentucky, from 375 samples. For the most part this species is to be obtained from loamy or sandy soils, either wet or dry to

very dry. It may be taken quite often from soils that have been cultivated and from soils where cultivated plants are growing.

Geolegnia septisporangia. In the initial collections (1925) this plant was taken only twice. Since that time the plant has been fairly commonly obtained in Wisconsin and Mississippi, a few times in New York, once in Oklahoma. Its habitat is very much the same as that for the preceding species (*G. inflata*). This form was not isolated from Kentucky soils, although it was taken thirty-one times from the above named states.

Pythiopsis intermedia. This plant, found originally at Chapel Hill, three times in 200 collections, has been secured twice since in 575 samples of soil: from near Sayre, Oklahoma, in red-clay-loam and red-sandy-humus (Red River bed), at depths of six and twelve inches, the soil being dry.

Leptolegnia subterranea. The plant was taken originally from Chapel Hill, eleven times from 200 collections. This form has been found since only in one locality: Clinton, Mississippi, during the summer of 1927, from loamy soil, depths of two, three, and five inches, all situations being dry ones; associated plant life: pine, cedar (juniper), and huckleberry.

Saprolegnia ferax. Since the initial isolations this species has been taken seven times from 575 collections of soil. The species grows vigorously on corn meal agar and on bits of hemp-seed, behaving normally, as if the plant had been taken from water. Sporangia and sexual bodies were formed in abundance. Plant found in moist or damp situations, from sandy soil to leaf-mold (humus), four times from Wisconsin (Madison), twice from Oklahoma (Sapulpa and Shawnee), and once from Georgia (Dublin). Not taken from below seven inches depth.

Isoachlya eccentrica. Reported only once before the writer's first paper, this report being from the type station (Coker, 1923). The plant was taken five times at Chapel Hill during the winter months (1924–25) from the soil at depths down to seven inches. This species has not been secured since from the soil, although it was taken once from a water sample.

Achlya caroliniana was isolated twenty-seven times from 200 collections at Chapel Hill, during November and December, 1924, and during February and March, 1925, taken mostly from sandy to loamy soils; also several times from clayey soils, and a few times from manured soils, noticeably from cultivated areas, both dry and wet situations, from

depths of one to twelve inches. Since the work at Chapel Hill the plant has been found only once in 575 collections over widely separated areas, this time from Clinton, Mississippi, near the campus of Mississippi College: from humus-loam, surface soil, dry. The vegetation associated with the soils of the original 27 collections was quite varied: moss, grass, corn, *Spiraea*, *Photinia*, alder, sweet breath of spring, periwinkle, privet, honeysuckle, Spanish oak, hemlock, incense cedar, and juniper. A great number of the preceding plants were grown under cultivation.

A. flagellata was found sixteen times in the first 200 collections (1925), in practically the same situations as *A. caroliniana*. Contrary to the latter, *A. flagellata* has been found to be common in the soils of Wisconsin, Oklahoma, Mississippi, and New York, however, not being found in Kentucky, where *A. imperfecta* was the predominant form. *A. flagellata* has been secured 34 times in 575 collections.

Achlya imperfecta was isolated by the writer for the first time from Richmond, Ky., May 12, 1928, although Coker and Braxton (1926) report it from the soils near Southport, N. C. This plant was taken ten times in Kentucky and it is strikingly noticeable that it is the only *Achlya* species isolated from that state. Careful observation made upon each culture containing this species disclosed the fact that the plant was *A. imperfecta* rather than *A. flagellata* which is so common elsewhere. Secured from depths to seven inches, compact dark loam or ordinary loamy soil, medium to dry situations.

Achlya glomerata, not taken previously by the author, was secured by him three times near Clinton, Miss., June 9, 1927, in samples of soil taken from the edge of a peat-marsh. The plant was found twice in compact sand, once in loose sand; twice at the surface and once at a depth of five inches, wet situations. Vegetation associations: bracken fern, quackgrass, sphagnum, and sweet-gum.

Achlya hypogyna and *A. racemosa* were found only once each, and that at Chapel Hill in the original work (1925), being found in the same collection with *A. caroliniana*, *Leptolegnia* sp., and *Pythium monospermum*: sandy soil, at a depth of one inch.

Achlya subterranea, taken four times and described by Coker and Braxton (1926), was isolated once by the writer from a sample of soil taken near Shawnee, Okla., Jan. 1, 1927. The writer recognized this as a possible new species, which was confirmed by the appearance of the description by Coker and Braxton. The above sample was from dry red loam, near the surface.

Thraustotheca clavata has been secured eight times in 575 samples (six times previously at Chapel Hill), soils being taken from Wisconsin, New York, and Kentucky. It is of interest to note that the plant has appeared mostly in cultivated or meadow soils, having much the same distribution as *Geolegnia inflata*, *G. septisporangia*, and *Brevilegnia diclina*.

Calyptralegnia (*Thraustotheca*) *achlyoides* Coker. This species was secured twice from the soils by Miss Evely Utter, student of the author, Feb. 6, 1927, samples being taken from dry sand, at the surface and at the depth of six inches, Shawnee, Okla. Found by the writer once again in water.

Dictyuchus sterile has been isolated six times from the soils since the appearance of the first paper in 1925: sandy lakeshore soil (wet), red clay-sand (dry), compact bog-humus soil (wet), dark meadow loam (dry).

Dictyuchus Magnusii has been isolated only one time from 775 collections, this being taken from a sample of soil secured from an old sandbed, at the surface, near the old pumping station, Clinton, Miss., June 14, 1927, a moist situation. It is of interest to note that the oogonia would mature only in the presence of sand in the water cultures.

Aphanomyces stellatus and *A. laevis* were secured a few times at Chapel Hill, but not once since. An unidentified species of *Aphanomyces* (probably) has been secured seven times form Madison.

Apodachlya brachynema. This rare form occurred twice in samples of soils from Clinton, Miss., June 9, 1927, at the end of a peat-marsh, from sandy humus and from white sand. The species was secured a third time from Madison (Wisconsin), but notes concerning this isolation were lost.

Allomyces arbuscula. Previously to the writer's first paper, this species had been reported only a few times: once from India (Butler, 1907), once from New York State (Barrett, 1912), and once from Chapel Hill (Coker, 1923). The author isolated this form the first time from the soil, securing it three times at Chapel Hill. Following the work at Chapel Hill, the plant has been taken 43 times in 575 samples of earth, twice from Wisconsin, once from Oklahoma, 27 times from Mississippi, twice from New York State (Lockport), eleven times from Kentucky. This species was found in loamy soils, especially soils around cultivated plants, at depths from surface to 13 inches, for the most part in dry to medium soils, seldom in a very moist soil.

Olpidiopsis species. Found twice at Chapel Hill, once parasitizing

Achlya species and once, before accurate data were kept, parasitizing *Aphanomyces* species. *Olpidiopsis* has been taken since twice at Madison, from black humus-loam and loamy soils, parasitizing *Saprolegnia ferax* and *Achlya* species.

Pleolpidium species. This rare form was found six times parasitizing *Allomyces arbuscula*, on some occasions the parasite being quite abundant; taken twice from Mississippi and four times from Kentucky. As far as the author can find, the plant has not heretofore been reported as parasitizing *Allomyces*. He can find only two references, whatever, to this form, and then the parasite is found in *Monoblepharis* (Cornu, 1872; Fischer, 1892).

This paper is concerned with the true watermolds or with the watermold-like forms; however, to a certain extent, a careful record has been kept of the Pythiaceae. Not all of these forms have been identified, but the paragraphs below will give an idea of their distribution.

Pythium deBaryanum has been found to be abundant in all sections of the country, where the author has worked, being taken 86 times in 775 collections, from North Carolina, Wisconsin, Oklahoma, Mississippi, Kentucky and New York. The plant is probably more prominent in the southern states. It may be found commonly to a depth of twelve inches, in all types of soil, with a variety of vegetation.

Pythium monospermum isolations have been largely confined to North Carolina, having been taken 30 times in that state, four times at Madison (Wis.) and once from Oklahoma. This species has about the same habitat as the first species.

Unidentified species of *Pythium* have been secured 121 times from the soils over the several states where researches have been carried out. A form of *Pythium* was taken once from a depth of 65 inches, vertically, from the face of the excavation for the new Wisconsin Memorial Union Building at Madison, the sample being secured several inches deep inward, horizontally.

SUMMARY AND CONCLUSION

1. During the early stages of the writer's researches it was found for the first time (two species of parasitic *Aphanomyces* excepted) that many species of the Saprolegniaceae are contained in the soil, and that some are much more common in the soil than in the water.

It is of extreme interest to note that no previous worker has mentioned the true watermolds as being obtainable from the earth, although these

molds commonly may have been taken in water samples from temporary pools a few days after a rain. Since the spores of watermold species are not transported in the air, it is reasonable to believe that in the case of a temporary mud puddle or pool the various forms of Saprolegniaceae are present in the soil on which water comes to lie, and as a result, their spores become obtainable from the water in the pool.

Many workers have isolated ascomycetous forms and zygomycetous forms from the soils, especially from humus soil. Saprolegniaceous fungi are not so abundant in humus soils, which may partly explain why no one ever has found such a form away from water. Also the employed culture methods may explain why no one has ever secured watermolds from the soils. Previous investigators for the most part used agar plates, upon which soil was placed; from this soil spores were secured, which gave rise to mature fungous plants on the agar media. From these growths pure cultures of fungi were obtained.

The writer placed in water (distilled and autoclaved) the soil upon which experiment was to be made. He then proceeded with the regular culture routine as used for securing Saprolegniaceous species. A similar process had been used before only by Butler (1907), and possibly others, to secure *Pythium* species; in these cases none of the substrata favorable to the true watermolds were used. Although the writer's discovery was somewhat accidental, it was as a result of the question in his mind as to what became of the watermolds after a pool dried out, since the molds were readily obtainable from water later in the same pool. His question has been partly, but not wholly, answered.

2. Experimentation has been carried out in order to prove that the water used in the culture of these plants had no spores from which molds could be produced. In a case of ten collections from a given place, two parallel series of samples were secured, Nos. 481–490 (Wisconsin). One set was autoclaved before the placing of the substrata and the other series was cultured without autoclaving. The one series, when sterilized hemp seeds (cut in halves) were placed thereon and regular culture methods were followed, not a sign of growth of any form of life was noticed. On the other hand, growth was noted in practically every culture in which the soil had not been sterilized. The following table gives the variety of growths identified in the unautoclaved soil: 481, *Geolegnia inflata*; 482, *Geolegnia septisporangia* and ascomycetous forms; 483, *G. inflata*; 484, bacterial growths; 485, ascomycetous growths; 486, ascomycetes; 487, *Saprolegnia ferax*; 488, bacterial

growths; 489, *Pythium de Baryanum*; 490, *P. de Baryanum* and ascomycetous forms.

3. As a result of the work begun on the soil watermolds, a peculiar new genus, with two species, was isolated by the writer and described in his first paper. Also there were described in that paper two new species of established genera. Since that time a second new genus has been established by Coker and Couch (1927), and new species being contributed by these and the author. Many other new species of previously established genera have been found by the several workers among the soil watermolds.

4. Many of the soil watermolds, especially *Thraustotheca clavata*, *Geolegnia inflata*, *G. septisporangia* and *Brevilegnia diclina*, as well as *Allomyces arbuscula*, seem to be quite abundant in cultivated soils or in soils that have remained idle after cultivation. These species have been often associated with *Pythium* species.

5. These soil watermolds, except in the case of *Geolegnia* species and to a certain extent in *Brevilegnia* species, when cultured, produce sporangia which give rise to swimming spores, as found in the water forms. Sexual reproductive bodies are produced in abundance in all forms, excepting those in which such bodies have not been demonstrated.

6. The parasites common to the Saprolegniaceae in the water, occur also with the molds obtained from the soils. One noteworthy parasite is that which was found on *Allomyces arbuscula* a number of times, *Pleolpidium* species (Cornu, 1872; A. Fischer, 1892).

7. Cultures containing growths of *Brevilegnia megasperma*, *Achlya flagellata*, *Geolegnia septisporangia*, *Pythium deBaryanum* and ascomycetous forms, have revived quickly after cultures containing these species were dried out completely and kept dry for a period of seven months. Upon reviving, these were taken through the regular culture processes and the plants behaved normally.

The experimenter plans to continue his work in the isolation of the Saprolegniaceous flora from the soils. It is also his intention to extend this field, if possible, into the field of pathology, in his attempt to parasitize certain seed plants with species of the Saprolegniaceae.

In conclusion, the writer wishes to express his thanks to Dr. E. M. Gilbert for helpful suggestions and criticisms. Also to Dr. W. C. Coker does the author owe appreciation for timely suggestions during the progress of these researches.

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EXPLANATION OF PLATES

PLATE 32

BREVILEGNIA MEGASPERMA

Fig. 1. Habit of plant growing on hemp seed. Note young oogonia, young and mature sporangia and gemmae. × 120.

Fig. 2. An entire almost mature sporangium. The central vacuole with its cleavage furrows are prominent at this stage. Double branching sometimes occurs. × 405.

Fig. 3. A mature sporangium with a secondary sporangium by proliferation. × 405.

Figs. 4–5. Sketches to show the characteristic sporangial proliferation and characteristic sporangial structure. × 405.

Fig. 6. A resting body germinating in place. × 405.

Fig. 7. A cluster of oogonia with mature eggs and empty antheridia. × 405.

Fig. 8. A single oogonium. × 405.

PLATE 33

BREVILEGNIA MEGASPERMA

Fig. 1. Peculiar method of proliferation of oogonial branches. × 345.

Fig. 2. A terminal oogonium with maturing egg and an intercalary sporangium. × 405.

Fig. 3. Habit showing method of branching, an immature oogonium, and accessory spores germinating in place. × 405.

Figs. 4–8. Drawings made at intervals of 15, 10, 10, and 20 minutes each to show manner of spore discharge, common to the species. Also the method of hyphal proliferation is shown. × 405.

Fig. 9. An oogonium with a mature egg and a probable empty antheridium. × 405.

Fig. 10. Oogonial habit (typical). × 405.

PLATE 32

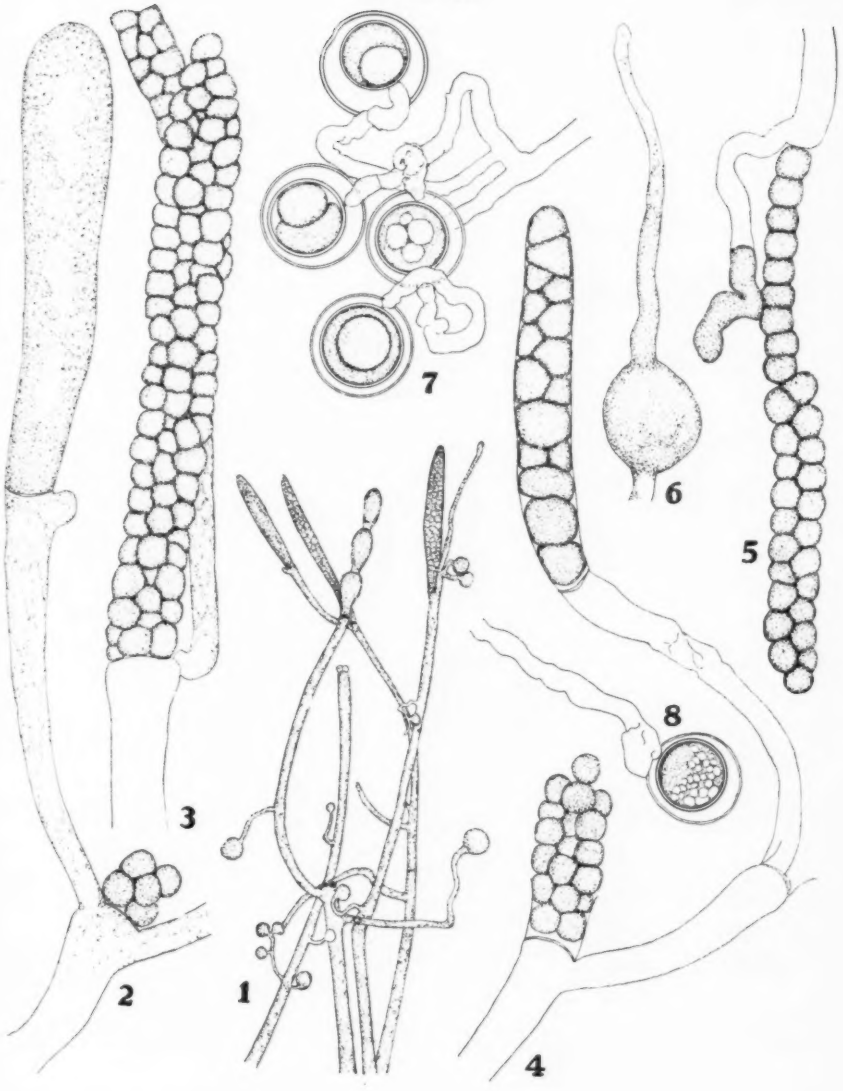

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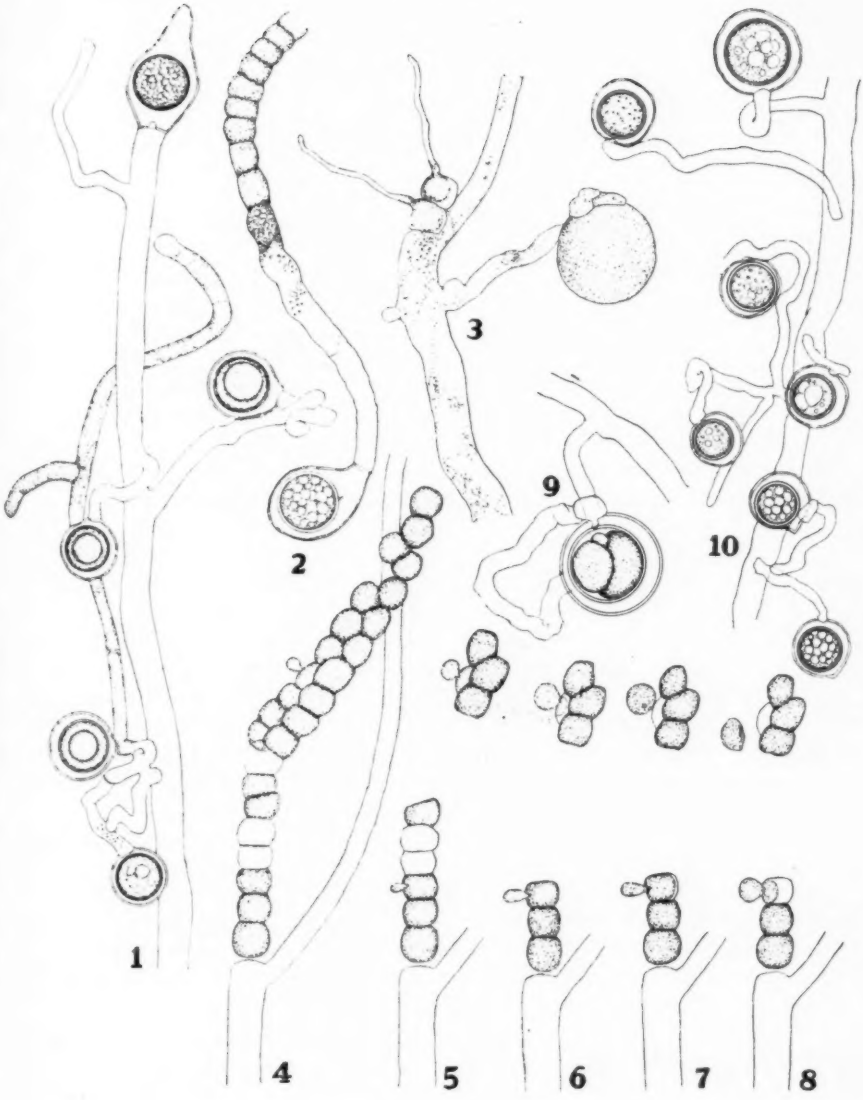
PLATE 33



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NORTH CAROLINA SCIENTISTS

By Roland M. Harper

The latest (1927) edition of "American Men of Science," a directory compiled by Prof. J. McKeen Cattell, and issued at intervals of several years, contains brief biographical sketches of about 13,500 scientists living in North and South America and the insular possessions of the United States, and a few in other parts of the world who were born in this country or have studied or worked here. Although one can easily think of some worthy scientists who are omitted, there are quite a number in the book who are mere teachers or practitioners of science rather than investigators; and the same is true of different parts of the country and of earlier editions, so that such discrepancies do not materially affect the value of the book for either geographical or historical comparisons.

The 1910 edition of the same work, which seems to have had the same standards for admission, included only about 5,500 names; so apparently the number of American scientists increased about 140% in 17 years. And the South has gained a little faster in this respect than the rest of the country. If the writer has counted correctly, the 1910 edition contains the names of 401 natives and 386 residents of 13 southeastern states, from Virginia to Texas, and the corresponding figures for 1927 were 994 and 1104. North Carolina's representation was 52 natives and 39 residents (including one part-time resident) in 1910, and 120 natives and 115 residents in 1927. So the number of native scientists in the state has increased in about the same ratio as in the whole country, but that of residents has increased faster, showing that the opportunities for scientists here are rapidly increasing.

Of the 1927 list, 28 are both natives and residents; so 92 native scientists have left the state, and 87 outsiders have come in from other states and countries. The tendency of scientists to migrate (and incidentally gain experience) is evidently much greater than in the rest of the population, for in 1920 only 6.1% of the white inhabitants of North Carolina (perhaps 10% of the adult whites) were born in other states, and 14.5% of those born in the state (perhaps 25% of the adults) were living in other states. In the following pages several different kinds of

statistics will be given for three groups, designated for brevity as emigrants, "stay-at-homes," and immigrants. It should be borne in mind, however, that most of the "stay-at-homes" have studied or worked in other states at some time in their lives. In some cases only two kinds of statistics are given, for natives and immigrants, or emigrants and residents; the first and last groups overlapping, and both including the "stay-at-homes."

The native scientists include 115 men and 5 women, apparently all white. Their principal birthplaces, by counties, are as follows:—Wake 12, Orange 7, Forsyth and New Hanover 6 each, Catawba, Guilford, Perquimans and Wayne 4, Anson, Burke, Edgecombe, Mecklenburg and Rowan 3, and so on down. By cities and towns they are as follows:—Raleigh 10, Wilmington 6, Chapel Hill 5, Winston-Salem 4, Morganton 3, Hertford 3, and several other places one or two each. In 1880, the census year nearest to the time when the average scientist of today was born, there were only four cities in North Carolina with over 5,000 inhabitants, and they contained only 2.9% of the state's population; but 15.3% of the native scientists were born in them (or so near them as to claim those cities as their birthplaces), or in fact in the first three. Evidently scientists are much more likely to be born in cities than non-scientists are; and this tendency is not peculiar to North Carolina.

The birthplaces of the immigrants are as follows:—South Carolina 9, Massachusetts and Ohio 7 each, Virginia 6, New York and Indiana 5, Pennsylvania and Maryland 4, Michigan, Nebraska and Tennessee 3, and several other states and countries one or two each. The number of foreigners is six. The present location of the emigrants is as follows:—New York 20, District of Columbia 8, Pennsylvania, Tennessee and Georgia 7 each, Massachusetts and New Jersey 6 each, California 4, Maryland and Ohio 3, Alabama, Mississippi and Indiana 2, and 11 other states and Mexico 1 each. Only one has gone to Virginia, and none to South Carolina, strange to say.

The location of scientists within the state is of course determined largely by educational institutions. Chapel Hill has 40 of them, Raleigh and suburbs 34, Durham 12, Asheville 6 (including five at the forest experiment station and one man who spends part of his time outside the state), Greensboro 4, Wake Forest 4, Wilmington, Winston-Salem and several smaller places one each (and Charlotte none!).

The average age, at the middle of 1927, of the 92 emigrants was 46.4 years, of the 28 stay-at-homes 47.5 years, and of the 87 immigrants 44 years.

About 97% of the whole list are college graduates. The emigrants received their bachelor's degree at the average age of 21.6 years, the stay-at-homes at 21.3, and the immigrants at 22.2. The colleges from which the natives (both resident and non-resident) received their first degrees are as follows:—North Carolina 51, N. C. State 13, Wake Forest 11, Trinity (Duke) 7, Davidson 4, Haverford 3, Guilford 3, South Carolina 3, and 19 others one or two each. The immigrants represent 56 different colleges, the leading ones being Ohio State 5, Princeton, Johns Hopkins, North Carolina and Clemson 4 each, and Michigan, Nebraska and Missouri 3 each.

About 84% of the emigrants, 70% of the stay-at-homes, and 67% of the immigrants have doctors' degrees, mostly Ph.D., but some Sc.D., medical or honorary. The first group received such degrees at the average age of 30.4 years, the second at 32.5 and the third at 29. The principal sources of doctors' degrees, for all combined, are Johns Hopkins 24, Cornell 14, North Carolina 12, Columbia 10, Chicago 10, and Harvard 7.

The showing of Chapel Hill is remarkable; not only in natives and residents but also in bachelors' and doctors' degrees. It is without doubt the most typical college town in the South, most others of its size being diluted, so to speak, by factories, etc.[1] In the absence of any exact figures on its population in 1927, we might say roughly that about one in every fifty of its inhabitants is a recognized scientist (as compared with about one in 9,000 in the whole United States). Or if adults only are considered, about one in thirty is a scientist; or if men only, about one in 15.[2] Raleigh too makes an excellent showing in these matters, for a city of its size.

The scientific specialties of the emigrant scientists may be classified roughly as follows: Chemistry (including physical and physiological chemistry, etc.) 30, medical sciences 18, zoology (including "biology") 8, psychology (including education and psychiatry) 7, agricultural sciences 7, botanical sciences (including forestry and plant pathology) 6,

[1] See Scientific Monthly, **30**: 165–166, 1930.

[2] In 1920 one in every 48 inhabitants of Chapel Hill, or perhaps one person in every dozen families, was listed in "Who's Who in America," a ratio perhaps surpassed by no other community in the country, though Princeton, N. J., is very close to it. And Princeton resembles Chapel Hill in some other ways, as every one who has been in both places will recall. In the whole United States there are about twice as many "Who's Who" people as scientists, and in some states three or four times as many; but in Chapel Hill the numbers are more nearly equal, 40 scientists in 1927 and 49 Who's Who people in 1928.

physics (with electrical engineering) 6, geology 6, mathematics 4. Of the stay-at-homes, chemistry (including pharmacology) 8, mathematics 5, medical sciences 5, and a few others 1 or 2 each. Of the immigrants, botanical sciences 19, zoology (including embryology) 16, physics (and electrical engineering) 8, engineering 7, psychology 7, geology 6, agricultural sciences 4, and mathematics 3. From these figures it seems that North Carolina has produced more chemists and medical scientists than it could use, but has had to import most of its botanists, zoologists and engineers. But these generalizations are based on rather small numbers, and may not have much significance. (It will be interesting to see if the same relations hold a decade or a generation hence.) There is only one geographer in the whole list, and not a single sociologist. but those branches of science seem to be very inadequately represented in Prof. Cattell's book, and were not considered at all in picking the thousand leading scientists, for some reason.

Eight of the emigrants and nine of the immigrants (but none of the stay-at-homes) have stars after their names, indicating that they are among the leaders. But these figures may not mean much, for the stars are determined by vote, and thus prestige and popularity count as much as ability. And a man who has spent most of his life in one state is not likely to get as many votes in a nation-wide popularity contest as one of no greater ability who has traveled around more. A few of those marked as leaders have done no original work for twenty years or more, and are simply "resting on their laurels," for Professor Cattell's stars when once awarded seem to be retained for life.

Another source of information about North Carolina scientists is the latest directory of the American Association for the Advancement of Science, published late in 1929, containing about 20,000 names and addresses, with notes on education and position, but not nativity or age. The members are divided into two principal categories, namely, fellows and ordinary members. The fellows, who constitute between one-fourth and one-third of the total, are elected to that honor, and are supposed to be real scientists, engaged in research. Some of the other members may be real scientists too, but the majority are beginners, students, teachers, commercial chemists, philanthropists, etc., who are interested in science but have contributed little or nothing to scientific literature.

In every state the total number of A. A. A. S. members is greater than the number of scientists listed in "American Men of Science," while the number of fellows is less. Practically every fellow is in

"American Men of Science," and nearly all scientists are members of the A. A. A. S., though there are a few who have never joined the Association, perhaps because they can see the publications to which members are entitled in the institutions where they work.

The A. A. A. S. directory includes a few members who have resigned in the last few years, but they have been counted with the rest, for the sake of simplicity. The Association is divided into 16 sections, corresponding with different sciences, and each member can belong to as many sections as he likes, without additional cost. The sections to which each member belongs are indicated in the directory, except that there are some, mostly of the philanthropist type, who have never expressed preference for any particular section.

The A. A. A. S. is represented in North Carolina by 191 members, including 56 fellows. One of the fellows and 29 of the other members are women. Forty-four of the fellows and an equal number of other members (including six of the women) have doctors' degrees.

The leading sections chosen by the North Carolina members are as follows, with the number of members assigned to each, and the number of fellows in parentheses. Zoology 50 (17), botany 42 (13), chemistry 37 (6), medicine 29 (4), agriculture 19 (12), physics 18 (4), education 18 (3), geology (and geography) 17 (6), engineering 15 (4). Considering the women separately, their preferences run in approximately the same order, namely, zoology, botany, medicine, chemistry. All these figures involve some duplication, on account of many persons choosing more than one section, but the sequence is of course not very different from that obtained from "American Men of Science," for it is based largely on the same individuals.

By residence the A. A. A. S. members in North Carolina are distributed as follows (with fellows in parentheses as before). Raleigh and suburbs 36 (16), Chapel Hill 33 (21), Greensboro 26 (3), Durham 20 (7), Asheville 17 (5), Charlotte 6 (0), Davidson 6 (0), Salisbury 5 (0), Beaufort 4 (1), Winston-Salem 4 (1), and several other places 3 or fewer. Greensboro has more members who are not fellows than any other city (mostly at the State College for Women), but Chapel Hill leads in fellows. Charlotte, Winston-Salem and Wilmington make a rather poor showing in proportion to their size, as they did in "American Men of Science."

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FUTURE OF THE OYSTER IN NORTH CAROLINA

By R. E. Coker

I. The Oyster and Political Theory

The Problem

Undoubtedly the oyster represents one of the greatest of undeveloped resources in North Carolina. Individual estimates of the aggregate area of potentially productive oyster bottoms may be exaggerated or they may be overconservative; but certainly North Carolina has in its broad sounds, bays, and salt "rivers" a great underwater area suited for the production of marketable oysters, greater, probably, than that of any other state except Maryland. Comparatively recent statistical surveys show the following annual yields in bushels of oysters for the leading oyster-producing states of the Atlantic and Gulf seaboards (adapted from reports of the U. S. Bureau of Fisheries):

Virginia	4,356,416
Maryland	4,252,860
New Jersey	3,706,956
Mississippi	1,696,422
Connecticut	1,145,756
New York	1,080,585
Louisiana	1,022,109
South Carolina	718,906
North Carolina	559,628

It will be seen that neither of the states that have the greatest possibilities in oyster culture are at the top of the list, North Carolina being indeed very far from the top. This alone seems very strange, but the condition is even more arresting if we consider only the product of *oyster culture*, as distinct from the yield of the public fishery. Too many statistics are an annoyance, and we need only say that, when we include every eastern oyster-producing state from Massachusetts to Texas, sixteen states in all, Maryland is eighth on the list and North Carolina is sixteenth. Those who wish the figures may consult the table at the end of this article. Obviously, we can not even "Thank God for South Carolina"—or Georgia or Delaware. One who was acquainted

only with the physical conditions of the waters and bottoms of the Atlantic and Gulf seaboards and was then informed that Mississippi oyster farms produced nearly half a million bushels of oysters and Virginia farms more than one and a half millions, would expect of course to hear the yield of North Carolina stated in millions. Actually it is less than two thousand. Why is this so? Can the admittedly great possibilities for cultivation of oysters in this state be capitalized? And if so, how?

It is very easy to propose a plan for the development of oyster culture, if we consider only the existing physical and biological conditions and disregard those obstacles that may be described as social or as political in the best sense of the word. We will come to that; but, first, in any effort to solve a problem that has long remained unsolved, it is certainly desirable to start from a base of established facts and principles.

Conditions of an Important Industry

In the first place, it had as well be recognized that no state or country anywhere has ever maintained for any great length of time a relatively important oyster industry based solely upon exploitation of the natural beds. A permanent oyster industry of importance depends upon some sort of aid to the natural processes so radically disturbed by the pursuit of an aggressive fishery. In other words, the development of the resources, or even their mere maintenance as a significant basis of industry is conditioned upon planting or cultivation. If the statement seems dogmatic, we have made it so in the belief that no one informed of the conditions maintains the contrary. Maryland might seem to be an exception, but she does not, as we understand, claim to be such, realizing that, while her product is large as compared with those of most other states, it is small for the enormous area of her potentially productive bottoms. Contrast the superior production of Virginia to that of Maryland having many times the area of shore waters possessed by the Old Dominion.

In the second place, we believe it may be recognized that nowhere in America, if anywhere in the world, has oyster culture as a public enterprise been distinctly successful. In fact, only Maryland and North Carolina seem at any time to have thought it advisable to go extensively into the business of replanting depleted beds by state action. It was an effort to do something, but if there were good results they seem not to have been economically measurable. Yet it must be said that these states did not really attempt oyster culture; they only planted oysters

or shells for "set". *Planting* and *cultivation* are different matters, as any land farmer might suspect, but as many persons, without discredit, overlook when considering the oyster.

This leads us to a third basic fact or principle, which is that oyster culture, where it has been successfully pursued on any large scale, has been found to be a very exacting sort of enterprise, with more or less constant demands on the attention, the time, and the intelligence of the planter. Oyster farms are watched and cultivated in various ways. Overcrowded clusters must be broken apart, the oysters may be taken up repeatedly for this and for other purposes; they may be transplanted from one bottom to another several times to develop size or form or flavor; they may be worked over time and again to remove enemies; in the end, they are harvested according to some definite plan. Oyster farming is not a flourish but an occupation.

No doubt the generally unhappy ventures in public planting have been based upon a somewhat natural assumption that we may follow Nature's methods in developing new beds. The fact is overlooked that Nature may have taken a hundred years or more to do what we expect to accomplish in a couple of years, and that she cared not how many failures she made in the meantime. She was not trying to make money. Seeking financial success, we must follow Nature's guidance with some discrimination. Who knows what may have been the tragic history of Harbor Island Rock during a dozen centuries before it knew the clank of oyster tongs? Nevertheless, the production and profitable maintenance of commercial oyster beds in North Carolina, as well as in every other state of the Atlantic and Gulf seaboards south of Maine, is demonstrably practicable.

It has been urged that the state can do whatever the private planter can do. Possibly that is true, but at best it is a theoretical proposition, and it would be wisest to try it out first, not on invisible oyster beds, but on visible land crops, such as cotton or tobacco or, better, livestock, under strictly competitive conditions as to employment of labor and supervision. Then, if previous practices in state oyster planting were to be followed, the public would be given a fairly free hand in the harvesting—and this would render a complete accounting impossible! No one seems yet to have advocated that the state handle the oyster planting enterprise to the very end, including the harvesting. We mention this only to make it well understood that we are not discussing state farming of oysters in a proper sense—something that seems not to have been attempted or proposed.

Possibly it would serve in some degree to clear the atmosphere of discussion if we could think of oyster farming as rather less like forestry than like poultry or stock farming, without the feeding problem, it is true, but with plenty of other problems peculiar to the business. We may say again that oyster farming is not a mere matter of sowing seed; it is a steady job.

The Greatest Obstacle

If we may then take it as at least a provisional assumption that the oyster of the future is to be dependent upon oyster farming as a private enterprise of an exacting nature, we may proceed to a consideration of the chief obstacles to the development of this enterprise in North Carolina. We do not believe that there have been any serious economic difficulties in the way of oyster farming in this state, other than one—and that a very serious one. It is the practical difficulty of giving a valid title or lease to the prospective planter (and of convincing him of its validity—a necessary corollary to the main principle).

Where oyster culture is practiced on a scale, leases to bottoms are granted either in perpetuity or, more commonly, for a reasonable term of years; and only lands previously determined to be non-productive of oysters in a commercial way are open to lease. That is to say, the public cedes none of its rights to existing oyster grounds, but grants only the right to develop previously unproductive areas. This, on the face of it, is ideal. No one loses any right, except the right to take oysters where there have been none to take; so that what the planter produces is so much net increase in the state's yield of oysters, so much clear profit to the state, economically speaking.

As it was in the past, the trouble came four or five years later when the new beds had become productive and the planter found the poachers removing his crop. Legal action followed, of course, but the poacher and his friends maintained that the ground in question was always productive; and, since off-shore bottoms are difficult to locate in the memory with certainty, it is easy for the friend of the defendant to recall erroneously the precise locus of his oyster-taking operations of a time five or six years past. Possibly, too, there was some carelessness in the granting of leases. At any rate, a jury votes acquittal, and the privately developed farm becomes, to all intents and purposes, a public oyster bed.

It was very natural, then, that a long time ago large-scale planters, actual or prospective, gave up the effort and the thought of oyster farm-

ing in this state. Who would pay the state for the privilege of developing public oyster grounds? A good many years past, when it was the writer's privilege to visit most of the oyster-producing regions of Core and Pamlico Sounds, the only active oyster gardens were a few small holdings close inshore and managed by local citizens whose strength of character commanded an unusual degree of respect from possible poachers. Recent statistics suggest that this condition is as yet little changed. That there is now promise of change gives ground for encouragement.

In Maryland, about twenty-five years ago, the state undertook to prevent effectually the failure of its leases by having made at considerable expense a comprehensive official survey which was to settle for all time the question of the validity of future leases. She was so successful in making her law iron-clad that she found herself virtually bonded to protect the lessees in the rights granted them. When the oystermen, unable to upset the leases in the easier old fashioned way, forced the Legislature to repeal the leasing law, consequent proceedings in the state courts required a succeeding Legislature to vote a very large sum to indemnify the dispossessed lessees. Thus the protection was given in an unexpected way. Such a situation would not, we are sure, arise in North Carolina, yet the experience of other states, most of whom have successfully resolved the difficulties, points to the need to take full cognizance of local feelings, and to be resolute in the application of an adopted policy.

What we have tried to make clear is that the real obstacle to oyster culture, and, as we believe, to the whole future of the oyster industry in North Carolina, has been a political theory that is or was prevalent in coastal regions. This theory holds that underwater areas are and must always remain open to the public regardless of their comparative utility as privately developed areas or as practically barren areas. The theory may not generally be put into words; it may not even be registered as a theory in the consciousness of those who uphold its practice—but it was operative at the critical time a good many years ago when the state made its first beginning (and ending) in commercial oyster culture; it merits respectful consideration and sympathetic understanding. Where the theory has governed, as in Maryland and North Carolina, the states of greatest potentiality in oyster planting, there is little or no oyster culture. Where that theory has long been discarded as a rule of control, as in Connecticut, New York, Louisiana and Virginia, oyster culture is a prominent industry, but presumably one of less magnitude than might develop in the states more favored by nature.

It happens to be our personal opinion that the theory of public ownership of submerged lands is correct, but that its extreme application to the point of preventing development through a system of leasing is ill-founded and unwise; that its application to this extent is against the public interest. This is our opinion, the people who control may concur or dissent; we merely invite general consideration of a point of view that prevails in all states where oyster culture is a significant industry, where oyster production has been at any time distinctly and permanently increased. As a matter of fact, a non-leasing policy is, in all probability, contrary to the interest of the independent oysterman, meaning the man who will not lease, but will work only public beds. Obviously, this statement should be explained, but the explanation leads us inevitably into a discussion of the strange life history of the oyster and of the significance of the special conditions of North Carolina waters in relation to that story.

II. THE OYSTER AND THE OYSTERMAN

We have directed attention to the fact that North Carolina's vast possibilities in oyster production were quite undeveloped. We have pointed out that the relatively insignificant state of the industry was associated with the absence of oyster farming. We have attempted to show that the maintenance of an oyster industry in any way commensurate with the possibilities of the case is always dependent upon private oyster farming, an enterprise that is exacting in its requirements of the cultivator but by no means beyond the capacity of our potential planters.

Does it seem a curious fact that, while our eastern seaboard needs all the productive enterprises it can maintain, we nevertheless allow the great acreage of potential oyster plantations to lie—ready to produce wealth, but fallow? So it is and the explanation we find to rest on our inability under past conditions to protect lessees who might have the enterprise to unlock the potential stores of wealth residing in our undeveloped bottoms.

We have subscribed unequivocally to the theory of public ownership of submerged lands, though we think it an illogical and very unwise application of that theory which involves the refusal even to lease for purpose of oyster farming, or having leased, to give effective protection to the lease-holder in the enjoyment of the results of his labor. Finally, we have expressed the opinion that the oysterman who will not lease but will work only on public beds, the man who in past has been most

commonly in opposition to large leases, may himself be a sufferer from the application of his own theory.

Now, since primary consideration should be given to the "independent oysterman," born and bred through many generations on the shores of our favored sounds, we may properly enlarge upon the suggestion that the lack of a leasing system is prejudicial to his interests as well as to those of the state as a whole. It is, indeed, the State and not the oysterman that owns the bottoms with all their possibilities. Nevertheless, the oysterman is, in more than one way, very close to the locus of possible operations: he will and properly he should play an important part in the solution of the general problem.

How Private Planting Benefits Public Oystermen

We need not repeat the common arguments as to community benefits through increase of local wealth, with greater opportunity for employment and greater tax yields for support of schools and roads. Such arguments are sometimes two-edged: they may be turned back with some familiar quotation about the accumulation of wealth and the decay of men. There are, however, at least three practical advantages that a successful development of private oyster farming seems to promise to the oysterman who works only on public beds.

(1) A well-developed oyster-farming business must, for its own best interest, so establish the North Carolina oyster in its proper place in the market that it may generally and in full pride go directly from oystermen or local shippers to the markets of Raleigh, Greensboro, and Charlotte, and also to those of Atlanta, Richmond, and Philadelphia, without being first adorned (for a consideration) with the title of "Norfolk." North Carolina oysters from private or public beds will be better-priced to the producer. This is an important point for all concerned: we pass it over briefly now and allude to it again in the last section.

(2) A local market would undoubtedly be established for seed oysters, the small oysters from the over-crowded and short-lived reefs of the broad border zone between fresh and brackish waters, where the oysters are annually destroyed by over-prolonged subjection to flood waters from the rivers. In New Jersey, Connecticut, and elsewhere, the sale of "seed oysters" is a big business for the "public" oysterman. Under our more favorable conditions, seed will never (let us hope) be so precious as in the northern states, but, with a great planting business, there should, none the less, be market for what we have, and this without robbing the public beds.

(3) The third advantage to independent oystermen, to be derived from commercial planting by others, is of much greater significance but is less briefly to be stated. We refer to something that underlies the whole life of the oyster industry. It has been a notable feature of our waters that a "set" is almost universally obtainable; that is to say, there is during the early summer an abundance of free-floating larval oysters ready to "set" or attach as "spat" to such "culch" (meaning old oysters, shells, rocks, and other solid objects) as may be available. Will it be so twenty, fifty years from now? Let us reduce that vital question to practical terms.

The Conditions of a Set

It may be hard to think of an oyster as a migratory animal; but it is so, while very young, and extremely so, if being carried by currents may be regarded as migration. It must be understood that oyster beds do not individually re-seed themselves; all of our useful oysters discharge their spawn into the water in which it is carried hither and yon by the variable currents. We do not see these swimming oysters, certainly not without a microscope; for they are so small that a million, it is said, can be held in a watch crystal. Nevertheless, as we sail over the sounds in proper season, the young and minute oysters, perhaps in great numbers, are everywhere beneath us and about us, rolling along, coming variously from this or that place, going we know not whither, to destruction or to the re-population of some oyster rock.

Any particular oyster bed is re-seeded from the common stock of floating larvae which fall where they happen to be when ready to "set." So it is that the "spat" of Pain's Bay may have developed from the spawn of Wyesocking or of Cunning Harbor and that two oysters living side by side may have been "born" miles apart. It must be clear, then, that an oyster bed is not self-continuing; it continues from year to year and from decade to decade, but it does not continue itself. Natural oyster propagation represents one of Nature's finest examples of "community effort."

We must now focus attention on this important "common stock" or "pool" of infant oysters, drifted helplessly by the tides, but carrying with it the future of all the oyster beds. We must remember, too, that while the floating stock is essential, it is of no practical use while it floats; to make marketable oysters, the larvae must at the right time sink, and so the conditions must be right for sinking. We are not here concerned with the further fact that, after they have sunk, they will be of no further use unless still other conditions are appropriate.

Our wonderfully favorable condition as regards "set" is due in part to the enclosed nature of our sounds, to the excellent conditions of internal circulation maintained by wind currents chiefly, and to the relatively general low salinity and correspondingly low specific gravity which permits the light larvae to sink through the water to the bottom. In brief, the larval oysters are kept within the sounds and in the vicinity of possible oyster beds while they grow to the stage of attachment; and, having arrived at that critical stage (and become heavier), they find themselves in water light enough in weight (because not too salty) to permit of their settling to the bottom. In the sounds they do not have to remain unnaturally afloat and die, as they often do in Long Island Sound. They do not have to find attachment at the surface between tidelines, as they must do to a very great extent in South Carolina and in some of our own harbors having water of high salinity—the homes of so-called raccoon oysters.

Now, as to the future with respect to this matter of set. The conditions of salinity and circulation in the sounds are not likely to be disturbed by the activities of man; but these are not the only conditions essential to a set. There must also be a sufficiently general distribution of breeding oysters, so that fertilization of eggs by sperm, which occurs in the water largely by chance, will be assured, and so that there will be such a density of floating larvae as will make a significant set. Once the beds are depleted beyond a certain degree, the fertilization of eggs must become less general and the floating stock of active larvae so thinned as a result of both insufficient spawning and inadequate fertilization, that an effective set would not be the general rule. Depletion of the oyster resources may very well come to the point where natural restoration is impossible. Our peculiar physical conditions have saved the set so far; will they do so indefinitely? There is room for doubt.

On the other hand, if there are large plantations of well-grown oysters, these do more than profit the planter; they serve as mighty contributors to the common pool of floating larvae upon which depends the future of all beds, both public and private. The oyster planter, if he would, could not restrain the seed floating up from his carefully tended acres from settling in remote places, on public or private beds, even on the bed of his dearest enemy, should he have one. Whether he will or no, the private planter contributes to that great "community effort" of nature to which we have previously alluded. Connecticut has the plantations, but, due in part anyway to higher salinity in Long Island Sound, it is common for her to miss the set. Our more ideal conditions

for successful propagation guarantee the set somewhere in North Carolina, provided we insure the proper abundance and distribution of breeders, which we may do through the encouragement of private planting.

The gist of this third argument is then that private farms may be expected to contribute in the way of propagation toward the permanent conservation of public beds and at least to this extent to protect the interests of the independent oysterman of the future.

Protection of the Oysterman who Lacks Capital

It must be added that the so-called "small oysterman" merits further consideration beyond that implied in the suggestion of several probable indirect benefits. Under any system of leasing his welfare can be guarded in another way. There is room for two kinds of oyster farms, which we may distinguish as *oyster gardens* and *oyster plantations*. In certain territory, as within bays, leases may be limited to small areas, within the means of the ordinary individual to secure and within his capacity to manage, while very large holdings are restricted to the offshore waters. Existing law recognizes this principle, whether or not the details are worked out to best advantage. We will probably not have an economically significant industry without large farms in offshore waters. The small farm in such regions is an impracticability. But that gives no reason for excluding the operator with small capital from direct participation in a developing industry, or for denying him the opportunity of working up in the business that is nearest to his life.

Some Points Merely Mentioned

It has been apart from our present purpose to speak of some of the more or less well-known advantages of our region for production of oysters, such as the lack of significant sources of possible pollution (deserving much emphasis) and the fact that the rate of growth of oysters in our waters is twice or probably three times as great as in the region of Long Island—certainly no slight consideration. We have been concerned merely with the conditions that have blocked development. We must, however, allude to a common misconception and to a need which that suggests.

There are those who think of the North Carolina oyster as different from the Virginia oyster or the Connecticut oyster. There is no North Carolina oyster. The oyster is a product of local conditions, and to

some extent, of manipulation. The oyster of the shores of Dare County is one thing, that of the Bight of Royal Shoal another; New River has its oysters, Harbor Island Rock produces something else. Suppose one matched a select lot of oysters from the last mentioned bed against the select "blue points" from Great South Bay of Long Island; but has anyone ever made a shipment of "selects" from Harbor Island Rock?

We have not organized our trade any more than we have organized production through cultivation. Possibly, we will not do the one without the other. There are market demands to be considered. The good prices are paid by discriminating buyers, and tastes vary. It was true a few years ago, at least, that the general market in one of our largest cities demanded a "fresh" oyster, one that would have been scorned at the favored oyster bars of Baltimore. Even individual buyers in our own local markets discriminate, if only to demand oysters with a foreign title, which may have been grown in Pamlico. The successful plantation manager will probably require areas in different regions that he may grow, shape and flavor his product to meet the varied requirements of the markets.

SUMMARY AND CONCLUSION

To summarize the chief of the simple points we have tried to make: We have called attention to certain facts: (1) That, by general admission, North Carolina has very great possibilities in the production of oysters, probably much greater than any other state except Maryland; (2) that, wherever oyster production has shown marked development, it has been on the basis of oyster farming as a commercial enterprise; (3) that North Carolina has no such enterprise to speak of; (4) that in oyster farming, according to Government statistics, she is at the very bottom of the list of oyster-producing states, being not even up to Georgia, which, as compared with this state, has almost no coastal waters. We have ventured several opinions: (1) that our failure to develop oyster farming, even to the degree in which it is developed in the least of the states, is due chiefly to an attitude which in the past has prevailed rightly or wrongly, with reference to the leasing of bottoms; (2) that this attitude is contrary to the best interest of the state; and (3) that it is contrary to the interest of all the oystermen.

He would be rash, indeed, who would maintain that there can be but one solution to a given economic problem. On the other hand, he is foolish who fails to give thoughtful consideration to the only solution that

common experience has yet adequately demonstrated or even promisingly suggested.

To conclude, one may be pessimistic and assume that a political theory as firmly entrenched in coastal regions as has been that of the right of public access to all submerged areas can never be overcome, and consequently that the future of the oyster industry, even the preservation of the now greatly reduced natural beds, is in the lap of the gods. Or one may believe that, as the coastal counties share with the remainder of the state in the sort of intellectual readjustment which leads to and goes with roads and schools and radios, some revision of thought may lead to a solution of one of North Carolina's most interesting economic problems—a solution that will serve the real interests of all concerned.

ANNUAL PRODUCT OF OYSTER FISHERIES

1923–26

(Based Upon Statistical Reports of the United States Bureau of Fisheries)

Total Product	*Bushels*	*Market Oysters from Private Farms*	*Bushels*
Virginia	4,356,416	New Jersey	1,591,103
Maryland	4,252,860	Virginia	1,573,338
New Jersey	3,706,956	New York	1,017,045
Mississippi	1,696,422	Louisiana	840,354
Connecticut	1,145,756	Connecticut	591,488
New York	1,080,585	Mississippi	404,136
Louisiana	1,022,109	Rhode Island	368,598
South Carolina	718,906	Maryland	158,006
North Carolina	559,628	Georgia	110,221
Rhode Island	369,098	Alabama	103,625
Texas	359,978	Massachusetts	75,893
Alabama	323,086	South Carolina	63,588
Florida	306,058	Delaware	62,146
Georgia	245,762	Florida	5,150
Massachusetts	99,693	Texas	3,000
Delaware	96,253	**North Carolina**	1,850

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CONTENTS

PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY..... 179

A PARASITIC ALGA, CEPHALEUROS VIRESCENS KUNZE, ON CITRUS AND CERTAIN OTHER PLANTS. *Frederick A. Wolf*..... 187

OBSERVATIONS ON MATING HABITS OF CYCLOPS. *L. L. Hill* and *R. E. Coker*..... 206

THE ECOLOGY OF THE INTERNAL PARASITES OF NIGERIAN RODENTS AND INSECTIVORES. *A. S. Pearse*..... 221

FURTHER OBSERVATIONS ON ASCIDIAN BLOOD. *W. C. George*..... 239

FLORA OF THE TRYON REGION. PART V. *Donald C. Peattie*..... 245

VEGETATION OF THE BLACK MOUNTAINS OF NORTH CAROLINA: AN ECOLOGICAL STUDY. *John H. Davis, Jr*..... 291

A TAXONOMIC AND MORPHOLOGICAL STUDY OF SOME MEMBERS OF THE SAPROLEGNIACEAE. *James Vernon Harvey*..... 319

NORTH CAROLINA SCIENTISTS. *Roland M. Harper*..... 333

FUTURE OF THE OYSTER IN NORTH CAROLINA. *R. E. Coker*..... 338

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